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THE UNIVERSITY OF ALBERTA

NUTRITION OF THE IRISH POTATO
WITH SPECIAL REFERENCE TO POTASSIUM

FACULTY OF GRADUATE STUDIES
DEPARTMENT OF PLANT SCIENCE
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by

Chi-tsung Tsai

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The undersigned hereby certify that they have read
and recommend to the Faculty of Graduate Studies for acceptance,
a thesis entitled, "Nutrition of the Irish Potato with Special
Reference to Potassium" submitted by Chi-tsung Tsai, in partial
fulfilment of the requirements for the degree of Master of Science.

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ABSTRACT

The Irish potato, Solanum tuberosum requires a higher level of potassium for optimum yields than do many other crops. The quality of tubers is also influenced by the level of potassium, particularly in reference to specific gravity and dry matter. Presently in Western Canada very little research information is available on which to base fertilizer recommendations for commercial potato production.

The investigations described in this thesis were initiated to provide knowledge on which to base potassium fertilizer applications for potato production. Correlations were established among tuber yields, plant tissue tests results, soil tests results and specific gravity of tubers. Field plots were established in 1963 and 1964 on three soil types: Winterburn fine sandy loam, Winterburn loam and Malmo silty clay loam.

The application of K_2O to the soil increased the available potassium level of each of the three soil types. The greatest increase was in the fine sandy loam and the least increase in the silty clay loam when original available potassium levels of the three soils were comparable.

Determinations of potassium levels in plants indicated that the percentage potassium in the leaf petioles at midseason was higher

in plants grown on the loam soil than in those grown on either fine sandy loam or silty clay loam. Results of plant tissue analysis provided somewhat better correlations with tuber yields than did the results of soil analysis.

Significant increases in tuber yield in response to potassium fertilizer application were obtained in four of the six tests. Increases in yield were greatest on the fine sandy loam but total yields were greatest on the silty clay loam. In each of the six tests the highest yields were obtained with the application of 300 to 330 lb. per acre of K_2O .

Specific gravity of tubers was generally slightly lowered with the addition of K_2O .

The Bray system and the Willcox system of correlating yield to soil fertility were both found to be useful in the interpretation of yield data and the evaluation of the effect of K_2O application.

A fertilizer requirement table based on Bray's relationship was prepared to serve as a general guide in commercial potato production.

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INTRODUCTION

The agricultural soils of Alberta have long been considered to contain adequate supplies of potassium for the production of many farm crops. However soils which have been cropped frequently to Irish potatoes, a heavy user of potassium, may become depleted of the exchangeable form of this nutrient. With increased use of nitrogen and phosphate fertilizer in recent years, crop yields have been increased, and more potassium has been removed from the soils (24). Inadequate potassium supply in the soil is generally considered to retard the growth of plants, to reduce disease resistance and to decrease yield.

The proper application of fertilizers should maintain nutrient content at an optimum level in plants. Optimum nutrient levels should lead to profitable yield increases. Excess potassium application may cause a depression in tuber yield, and also a depression in the dry matter content of the tubers. A major difficulty in predicting potassium fertilizer requirements is the adjustment of applied fertilizer rate in relation to the potassium-supplying power of the soil. Such adjustment must be based on reliable correlations established from empirical results.

Investigations involving soil analyses, plant analyses and field trials as they relate to soil potassium availability, plant

nutrient concentration and crop performance, were undertaken to provide practical criteria on which to base fertilizer recommendations.

The objectives of these studies were: (1) to investigate potato yield responses as a result of increment rates of potash application on certain Alberta soils; (2) to evaluate the relationship between: (a) soil available potassium and potash application; (b) soil available potassium and potassium concentration in plants; (c) potato tuber yield and potassium concentration in plants; (3) to insert the data of potash applied and tuber yield into Willcox's system to evaluate the fertilizer effect on yield; (4) to derive the c_1 and c effect-factor of the Bray's equation to prepare a fertilizer requirement table as a guide for potato production.

REVIEW OF LITERATURE

I. GENERAL CONCEPTS OF SOIL FERTILITY

Fertilizer requirements of a given crop vary among the different soils, among fields of the same soil types, and under different levels of management. For this reason, some method of determining the fertilizer requirement of a particular crop on a given field is desirable. The chemical soil test is commonly used to accomplish this, although techniques employing the composition of plants or plant parts show promise of improving estimates of fertilizer needs (11, 49).

Certain major concepts, as stated by Bray, have a definite bearing on soil fertility in general and on soil test interpretations in particular. These are:

1. The Availability Concept. "This concept recognizes that different forms of nutrient in soils vary in their availability, and that it is often the relatively small amount of a rather highly available form which has the most influence on crop growth. The available soil forms may be defined as those forms present in the soil, variations in the amount of which are mainly responsible for variations in yield and response to added fertilizers. One of the major objectives in modern soil fertility studies is to measure these

available forms and correlate them with crop growth and response to fertilizers" (11).

2. The Law of the Minimum. "According to Liebig's law of the minimum, the yield is limited by that factor which is at the minimum; that is (in the extreme interpretation), that factor which is present in the least relative amount or intensity is the only one which limits yields". (11).

3. The Law of Diminishing Returns. "As developed by Mitscherlich and Spillman for plant growth, the law of diminishing returns states, in effect, that with each additional increment for a fertilizer the increase in yield becomes smaller and smaller". (11).

4. The Baule Percentage Yield Concept. "This concept states that the final yield is the product of all the factors in yield, and not a result of a minimum factor as asserted by Liebig. Baule expressed each nutrient level in terms of ability to produce a certain percentage of a maximum yield; that is, each amount of a nutrient possesses a certain sufficiency in terms of percentage yield. Where two or more nutrients are deficient, the final yield is the product of percentage yields". (11)

5. The Mobility or Elasticity Concept. To the foregoing concepts Bray has added the mobility or elasticity concept in soil

fertility, which states in effect, that the available soil nutrients have a variable availability which depends on the mobility of each nutrient in the soil and on the nature of the plant. Those with little mobility, such as phosphorus, potassium, calcium and magnesium, tend to support the Baule percentage yield concept. The mobile nutrients such as nitrate nitrogen and water, tend to add support to the Liebig idea of a limiting nutrient. This mobility concept incorporates the features of each concept which have been found applicable and provides an explanation of how and why they apply. (11, 12, 14).

II. NATURE OF SOIL FERTILITY

Fertile soils are soils which, except for nitrogen and water, have a large reserve of nutrients already present in available forms - forms which are available to plant roots, yet are relatively immobile in the soil. Even in infertile soils, these forms are usually present in amounts many times larger than any one crop can remove (11, 12, 14, 49).

These available but relatively immobile forms are the exchangeable bases such as potassium, magnesium, calcium, and manganese; the exchangeable or adsorbed forms of phosphorus; the precipitated forms of relatively insoluble materials such as calcium carbonate or the calcium phosphates. All of these can

accumulate in relatively large amounts in soils. It is these amounts, which have accumulated in the past as a result of previous treatments or natural processes, that are responsible for fertility in soils. The yearly release of nutrients from unavailable forms has, except for nitrogen, only a minor effect on the immediate crop, although it can have a major effect on maintenance of fertility over a long period (11, 12, 14, 29, 49).

Because these nutrients are relatively immobile, their availability to plants is limited by the nature of the plant, particularly the density and extensiveness of the rooting system. Therefore only plants with a vigorous and extensive root system can compete in such soils (11, 12, 14).

The availability of the mobile nitrate nitrogen is not much limited by the nature and density of the root system, since this form of nitrogen can diffuse to the roots and approaches 100 per cent availability in the rooting area. For this reason the prediction of nitrogen fertilizer needs for a period of years through soil testing becomes practical (11).

The elastic availability of the immobile soil forms is made possible by the large amounts present. Even in a deficient soil the amounts are several times larger than can be used by a single crop (11, 23). But the immobile forms have a very indefinite availability

to plants. Favorable seasons, favorable physical soil conditions, and good varieties all help produce higher yields. Under these optimum conditions the plants require the uptake of large amounts of nutrient on any one nutrient level. It is the larger, denser, and more efficient root systems produced as a result of these more favorable conditions that makes it possible for the plant to obtain the large amounts of nutrients needed. Although variable foraging can take place at any one nutrient level, maximum yields are impossible if the level is a deficient one, since a deficient level cannot be overcome by making the other conditions more favorable (11, 12). This is because the plant itself is responding to changes in other factors. If, for example, potassium is only 80 per cent sufficient for a given crop it will restrict yields by about 20 per cent over a wide range of productivity. With increases in yields the plants remove more potash but these yields will still be 20 per cent lower than what could have been produced with adequate potash (11, 12, 14).

The Baule percentage yield concept holds only for the immobile nutrients (11, 12, 14). The mobile nutrients, such as water and nitrate nitrogen will act as limiting factors in the Liebig sense (11, 12, 14). A soil liberating only 50 pounds of available nitrogen from soil humus in a given area cannot produce crops containing more than 50 pounds of nitrogen. Some elasticity of use of this nitrogen within the plant is

possible, but it can not be compared with the elasticity provided by the soil plant relationship involving the immobile forms (11, 12, 14).

Thus Liebig's concept holds for culture solutions where all nutrients are soluble and hence cannot possibly have an elastic availability (11, 49); Baule's concept holds for all nutrients that are immobile (11, 48, 49). The mobility concept helps explain why these concepts work and where they apply (14). The plants will compete for mobile nutrients such as water and nitrogen in both broadcast and row crops. There is relatively little competition among row crops, however, for immobile nutrients (11, 12, 14, 48, 49).

III. THE POTASSIUM FERTILITY STATUS OF THE SOIL

The total potassium content of many mineral soils is about 2 per cent, which is equivalent to 40,000 pounds of potassium per acre in the plowed layer (49). But on many such soils, crops show profitable yield responses to application of as little as 200 pounds per acre of muriate of potash. The reason for this response is that the greater part of the soil potassium occurs in complex silicate forms that are too insoluble to supply potassium at a rate adequate to meet the optimum crop requirement. The amount of exchangeable potassium present in the soil at any time may be less than that removed by cropping in one season; yet the level of exchangeable

potassium in many such soils remains remarkably constant even under intensive cropping, indicating that the exchangeable potassium supply is replenished rapidly by conversion of the non-exchangeable potassium to the exchangeable form (9, 11, 23, 49). Many investigators have postulated the following equilibria between the different forms of soil potassium (9, 11, 49). Non-exchangeable K \rightleftharpoons Exchangeable K \rightleftharpoons K in soil solution. Thus removal of the exchangeable potassium either by cropping or by laboratory methods should cause conversion of some of the non-exchangeable potassium into the exchangeable form until the original level of exchangeable potassium is approximately restored (11, 23, 28). This amount of exchangeable potassium, which remains remarkably constant in many cropped soils from year to year and which can be altered only by potassium fertilization, apparently represents what may be called the characteristic level of exchangeable potassium in the soil (11, 23, 30, 49). Thus the total amount of exchangeable potassium found in a given soil at any time must be equal to the characteristic level of exchangeable potassium plus any increase in exchangeable potassium due to additions either in fertilizer or in crop residues. Obviously, knowledge of the characteristic level of exchangeable potassium affords a good measure of the inherent potassium supplying power of the soil, whereas the total exchangeable potassium content of the soil, as is commonly determined in laboratory methods, is useful in estimating the immediate need for potassium fertilization

(9, 11, 23, 28, 49).

IV. GENERAL ROLE OF POTASSIUM IN PLANT GROWTH

Elements essential to the life of plants may be classified as nutritive or regulatory (1, 40, 49). Potassium functions as a regulatory element (21, 40). Potassium is essential for many of the life processes of plants such as photosynthesis, carbohydrate production, hydrolytic activity of enzymes, carbohydrate transfer, nitrogen reduction (1, 40). Unlike nitrogen, phosphorus, calcium, and magnesium, the potassium ion does not enter into permanent organic combination in plants, but apparently exists as soluble inorganic and organic salts (1, 21, 40). Thus it is rather difficult to assign specific roles to it within closely related physiological processes (1).

1. Relation of Potassium to Nutrient Absorption

Potassium plays an essential role in the absorption of anions. Nitrate absorption is greatly accelerated in many plants by the presence of rapidly absorbable cations such as potassium and calcium. This relationship is not apparent, however, in all species of plants under all circumstances, because other factors may be dominant in relation to intake of nitrate (40).

In addition to its effect on absorption of nitrate, there is considerable experimental evidence to indicate that, directly or indirectly, potassium is essential for reduction of nitrate and perhaps for the later stages of protein synthesis (21, 40). Nightingale found that potassium-deficient plants of tomato contained no nitrite but did contain reserves of nitrate and carbohydrates. When the plants were shifted to a nutrient solution containing abundant potassium, nitrate nitrogen was then rapidly reduced to nitrite, and translocated to all parts of the plants (40). Furthermore additional nitrate nitrogen was rapidly absorbed from the medium.

Although potassium does apparently accelerate absorption and reduction of nitrate, with concomitant oxidation of carbohydrates or their derivatives, evidence in the literature shows that directly or indirectly, potassium along with other elements is an important factor in CO₂ assimilation as well (40). As Russell pointed out, the effect of potash in apparently bringing about more efficient photosynthesis is often to correct the adverse effects of an excess of nitrogen on fruit production (33, 55).

2. Relation of Potassium to Structure of Stems

There is an enormous volume of literature dealing with the influence of potassium upon structure of stems. Potassium is frequently recorded as favoring the development of thick cell walls

particularly exemplified in cereal crops by the formation of stiff straw. It has been emphasized that, directly or indirectly, potassium is essential for carbohydrate synthesis and therefore it is obviously important in relation to cell wall formation and stiffness of stems (1, 21, 30, 40). On the other hand, if nitrate reserves are high in relation to carbohydrates and if carbohydrates are not replenished through photosynthesis, at a rate that exceeds their utilization in respiration and protein manufacture, cell walls will be thin and stems structurally weak even though the plants contain an abundance of potassium (30). Although this element is an important factor in CO₂ assimilation, it is only one of many that may limit carbohydrate accumulation and consequently cell wall thickness and stiffness of stems (1, 30, 40).

3. Relation of Potassium to Cell Division

Except for simple salts of organic acids, it is not known that potassium enters into any organic combination in the plant (30, 40). Moreover, it is freely translocated from mature to meristematic tissues when there is a deficiency of it (40). Further, when developing fruits are present it is often in large part transferred to them, with subsequent death of vegetative growing points (5, 30). These facts have been brought out by many workers who have consistently emphasized the importance of potassium in the cambium and in other

actively growing tissue (5). This is true not only of aerial organs, but even more particularly of storage structures, such as the tap roots of sweet potatoes or beets. When potassium is insufficient for development of cambium like tissues of the sweet potato, for example, it is translocated from such tissue to the embryonic tip of the storage root and the potatoes therefore increase in length but little in diameter (5, 30).

These adverse influences of potassium deficiency on plant form are not peculiar to a lack of this element. Nitrogen deficiency will bring about much the same result, as would probably a lack of other comparatively mobile elements.

V. POTASSIUM FERTILIZER AND IRISH POTATO PRODUCTION

The Irish potato is a heavy potassium consumer. In California one acre of a good crop will remove from the soil 150 pounds of nitrogen, 35 pounds of phosphate and 250 pounds of potassium. From 70 to 90% of the nutrient will go to the tuber. Therefore, upon continuous cropping the exchangeable potassium level of the soil would be markedly depleted (37).

To cite one example, many California soils which have been cropped frequently to potatoes, show signs of becoming depleted of the exchangeable form of this nutrient. Samples from strips of

uncropped soil bordering on older potato fields contained up to four times more exchangeable potassium than did those from corresponding adjacent areas within the potato fields (37).

1. The Effect of Potassium on Yield of Irish Potatoes

Numerous field experimental data have been accumulated in the past few decades. The first reliable information on this matter was provided in the classical summary of experimental data made by Crowther and Yates. This well known work summarized the results of all experiments (in England) published between 1900 and 1939 (30). As various nutrient levels were used in the individual experiments, all yield responses were converted to those given by the "standard" levels of 25 units of N and 50 units each of P_2O_5 and K_2O (1 unit = 1.12 lb.). This was accomplished by substituting the obtained tuber yields in the response curve equation (29).

$$Y_1 = Y_0 + d(1 - 10^{-kx})$$

where Y_1 = yield with fertilizer; Y_0 = yield without fertilizer; d = the limiting response; x = level of fertilizer; k = a constant (= 1.1 for N and = 0.8 for P_2O_5 and K_2O) - value obtained from multi-level fertilizer experiments.

Ivins and Milthorpe also reported the optimal economic level of N, P_2O_5 , and K_2O for most soils to be 110, 120 and 190 pounds per acre respectively (30).

It is interesting to note that similar results were obtained by K. B. Tyler, et al. (51) in Santa Maria Valley of California. In these investigations, potassium fertilizers produced significant increases in yield in four of six field tests. The two fields which did not give significant increases from potassium had received heavy application of manure during the past years. Considerably higher yields were obtained from application of 200 lb. per acre or more of potash than from only 100 pounds (37, 51, 52, 53).

A number of field experiments incorporated with soil tests and plant analyses were conducted by Lorenz, et al. (36) on five California soils for a period of five years (1956-1960) to determine fertilizer requirements of potato crops. The information obtained from these experiments can be summarized as follows:

<u>lb/acre exchangeable K in soil</u> <u>(Air dry basis)</u>	<u>Plant Response</u>
< 200	Deficient, response to potassium fertilizer
200-300	Low, may respond to potassium fertilizer
300-400	Medium, response to potassium fertilizer unlikely
> 400	Sufficient, no response to potassium fertilizer

2. The Effect of Potassium on Tuber Quality

Evidence indicates that excessive amounts of potassium available in the soil tend to decrease both yield and specific gravity of tubers (6, 18). For a number of years, considerable data have been accumulated indicating that chloride in fertilizer salts are one of the causes of poor potato quality. An increase in chloride decreases the starch content and specific gravity of a tuber which are closely correlated with its baking quality or mealiness (66, 67). Dunn reported that carbohydrate production and ultimate starch accumulations are lower in tubers from soils treated with heavy amounts of chlorides than from other soils (18, 42). But Hoagland and Shricker found no difference in total starch content of tubers whether KCl or K₂SO₄ was applied (39, 50).

The commercial importance of the biochemical processes involved in blackening of potatoes subsequent to cooking has provoked intensive research. It is evident that the level of potassium in the tuber is involved. A high level reduces the tendency to blackening (39). There is also evidence that the iron, chloride and ammonium ions are indirectly concerned in the process, a high level of each causing greater tendency to blackening (30, 39).

Based on their work from 1951 to 1954, Eastwood and Watts reported that using a higher level of potash in potato production tended

to improve chip color slightly. Although the difference was not significant, the use of muriate of potash, in general, produced a slightly better chip color than did use of sulfate of potash. They considered that this effect was of little practical value as compared with other prominent factors, such as variety, climatic conditions, irrigation and nitrogen fertilization (20, 22).

Potassium has some effects on the keeping quality of certain fruits, but little effect in this regard on potatoes. According to Johnson, et al. (1956), it seems that different levels of potassium application have no effect on firmness of potatoes before or after storage. Furthermore, the different treatments did not make any difference in weight loss during the storage period (34).

3. Effect of Potassium on Disease Resistance of Plants

Potassium, as a major plant nutrient, is essential for vigorous growth and disease resistance of plants. Owen, et al. reported that both P and K will decrease the size of the late blight lesions caused by Phytophthora infestans. Arvo Kallio reported that increasing the potassium application from 120 lb. to 350 lb. per acre reduced the incidence of hollow heart from 77% to 42% (35).

VI. SOIL-PLANT RELATIONSHIP

There are a large number of mathematical expressions for the relationship between the amounts of various factors present, and the amounts of plant growth. A brief review is given of some of the more common functional models for which some biological justification has been claimed (49).

1. Mitscherlich's "Law of Plant Growth"

The magnitude of the effect on crop yield produced by a unit increment of one growth factor when the others were kept constant was originally given by Mitscherlich (1909) as follows: The increase in yield produced by a given increase in the growth factor is proportional to the decrement from the maximum yield which can be obtained by increasing that particular factor (44, 49). This statement can be expressed mathematically as follows:

$$\frac{dy}{dx} = C_1 (A - y) \dots \dots \dots (1)$$

where $\frac{dy}{dx}$ is the rate of increase in yield (y) produced by the factor (x), A equals the value of the maximum yield obtainable by increasing x under given conditions and C_1 the proportionality or "Wirkungsfaktor", which can be translated as "effect factor" or "efficiency factor".

On integration, equation (1) becomes:

$$-\ln (A - y) = C_1 x + K$$

or

$$\ln (A - y) = K - C_1 x \quad (2)$$

Since the yield y must be zero when there is no quantity of the factor present, $\ln A = K$ when $x = 0$, and substituting this value for K in equation (2) we get:

$$\ln (A - y) = \ln A - C_1 x$$

or

$$\log (A - y) = \log A - Cx \text{ where } C = 0.4343 C_1 \quad (3)$$

$$\text{Solving for } y : y = A(1 - e^{-C_1 x}) \text{ or } y = A(1 - 10^{-Cx}) \quad (4)$$

y represents the yield produced by the concentrations x of the growth factor and A the maximum yield.

2. Mitscherlich-Baule Equation

Equation (4), therefore, expresses the effect on the yield of a plant or crop produced by all concentrations of the factor. Baule has developed (1918) the aforementioned logarithimic theory of plant growth to deduce an equation governing the yield of a plant under all environmental conditions. He assumes that the plant is controlled by each factor in the manner stated by Mitscherlich, and his general equation is:

$$y = A(1 - e^{-Cx}) (1 - e^{-C_1x_1}) \dots (1 - e^{-C_nx_n})$$

where $x, x_1 \dots x_n$ represent the quantities of the factor and $C, C_1 \dots C_n$ are their respective "effect", or "efficiency factors". (61, 62, 65, 77).

A clearer idea of the nature of this logarithmic law can be obtained by making use of the conception of "food-units" originated by Baule. A "food-unit" is that amount of nutrient or growth factor which will produce 50 per cent of the maximum yield under given conditions when only one growth factor is being varied (44, 45, 49).

Mitscherlich's law states that the increase in growth per unit of factor is proportional to the decrement from the maximum. From this it follows that the addition of another 1 food-unit will give an increase of 50 per cent of the decrement; i. e., 50% of 50% = 25%, therefore the yield given by 2 food-units = 75%. In the same way, a total of 3 food-units will give $(75 + \frac{25}{2}) = 87.5$ per cent; for 4 units $y = 93.75$, for 5 units $y = 96.875$ and so on (44, 45, 49).

The numerical value of a food-unit expressed in ordinary units of weight and area varies, of course, for the different growth factors. It is related to the value of the effect factor and is equal to $\frac{0.301}{C}$. In the general equation $y = A(1 - e^{-C_1x})$, quantities y, A and x must necessarily be expressed in the same units, and are usually in the German units Doppelzentner per hectare (dz./ha.) for

field results (48). The equivalent units expressed in British system are one Baule unit = 76 pounds per acre for K_2O , 45 pounds per acre for P_2O_5 and 223 pounds per acre for nitrogen as worked out by O. W. Willcox (58).

3. The Application of the Law to Determination of the Nutrient Contents and Requirements of Soils

The application of the determination of nutrient requirements depends on the fact that Mitscherlich claims that the effect-factor in his yield law is a natural constant for each and every growth factor, and he defines a growth factor as "any physical or chemical, or if one likes, any biological growth factor which can exert an influence on the plant yield" (44). This assumed constancy of the effect factors and their independence on each other and on all external conditions of growth leads to a comparatively simple method of determining the nutrient contents of soils. Suppose a soil to contain a quantity "b" of a nutrient or growth factor; e.g., nitrogen, potash or phosphoric acid, and that the yield produced without any addition of nutrient is "yo" then the relationship between yo and b is given by the equation:

$$\log (A - y_o) = \log A - cb; \text{ therefore,}$$

$$b = \frac{\log A - \log (A - y_o)}{c}; \text{ or}$$

$$b = \frac{\log 100 - \log (100 - y_o)}{c} \text{ if } y_o \text{ is expressed}$$

as a percentage of A (48). Since it is assumed that the values of C_1 are constant, they can be determined once by experiment and the determined values used in the above equation; b can then be calculated if the value of A (the maximum yield) can be found from experiment or calculated from experimental data.

Upon application of Mitscherlich's theorem and Mitscherlich-Baule - equations, the soil nutrient status, b, can be determined immediately provided that either A or c is known. Since the b is determined in terms of Baule units, the rate of one unit of nutrient will give an increase of 50% of the decrement from the maximum yield; i. e., the 1st unit will give 50% of the maximum yield, the 2nd unit will give 1/2 of the 50%, the 3rd unit will give 1/4 of 50%, and the 4th unit 1/8 of the 50% (44, 48, 60). Therefore, this would provide the basis for economical consideration regarding the additional use of fertilizers; e. g., by calculating the cost of additional fertilizer and the price of the additional produce expected, the farmer can determine the best policy for his capital investment in fertilizer.

However, Willcox has made out a so-called "standard agrobiologic yield diagram" based on the Mitscherlich-Baule theorem. This would save the laborious computations involved if the original Mitscherlich-Baule equations were used (50, 57).

4. Bray's Modification of the Mitscherlich Equation

This modification has been used with apparent success in predicting potassium needs for many crops (3, 4, 9, 10, 11, 13).

The modified Mitscherlich relationship is:

$$\log (A - y) = \log A - (C_1 b_1 + cx)$$

where A = maximum yield (100%); y = observed yield (as per cent of the maximum); b_1 = soil test value (K); x = potassium fertilizer applied (lb/acre of K_2O); and C_1 and c are proportionality constants. This modified Mitscherlich equation provides the basis for yield prediction with the use of soil test values.

VII. PLANT TISSUE ANALYSIS

The objectives of plant tissue analysis are: (1) to aid in determining the nutrient supplying power of the soil; (2) to aid in determining the effect of treatment on the nutrient level in plants; (3) to study the relationship between the nutrient status of the plant and crop performance as an aid in predicting fertilizer requirements; (4) to help lay the foundation for approaching new problems or for surveying new regions to determine where critical plant nutritional experimentation should be conducted (54).

It is well known that certain elements are essential for plant

growth. Without these elements, growth decreases and finally fails completely during the vegetative or reproductive cycle of the plant. The exact concentration of the element required for growth will depend upon its function in the physical and chemical process of the plant (11, 54). Whether this concentration fluctuates within narrow or wide limits will again depend upon its function. Until the function of each element is clearly known, the practicality of plant analysis must be ascertained empirically through comparison of nutrient concentrations of plants restricted in growth to those of plants not so restricted by the nutrient. By such comparisons or correlation studies the "critical nutrient" levels for each element and for each crop can be established (11).

For a given nutrient the critical nutrient level may be defined as the range of concentrations at which the growth of the plant is restricted in comparison to that of plants at a higher nutrient level. Whether the "critical nutrient" concentration is a relatively narrow range of values, or fluctuates widely, is still a subject of investigation.

In plants in the field, the likelihood of a growth response from the addition of a nutrient to the soil will depend upon whether the nutrient concentrations of the plants are above or below the critical level. When the nutrient concentrations of the plants are above the critical level and remain there throughout the entire growth period, there is very little chance of a response in growth from addition of

more nutrients. Conversely, when the nutrient concentrations of the plants fall below the critical level, then the chance of a growth response under field conditions increases rapidly as the nutrient concentrations in the plant decrease. The magnitude of the response will depend upon the relative abundance of the other growth factors and upon the time and duration of the deficiency (17, 34, 54). When the relative abundance of the other growth factors are great, addition of the deficient nutrient will result in a relatively large increase in yield. When another factor or set of factors soon becomes limiting, however, then upon addition of the required nutrient, the yield increases will be relatively small. This small increase in yield will not be detected unless the error of the experiment is very low.

1. Plant Nutrient Concentrations

The nutrient concentration of the plant at any particular moment is an integrated value of all the factors that influenced this concentration up to the time the sample was collected (54). Specifically, these factors are the soil (S), climate (CL), time (T), plant (P), management (M), and possibly others. Expressed in the form of the plant would be a function (f) of the foregoing factors, thus

$$X = f(S, CL, T, P, M \dots\dots\dots) \quad (1)$$

Though the plant nutrient equation cannot be solved at present,

it nevertheless emphasizes the interrelationship of the factors and the fact that no one factor is entirely responsible for the nutrient concentration of the plant grown in the field. In a controlled environment in which the influence of each factor can be observed separately, the generalized plant nutrient equation would take the following form in a study of the influence of soil on the nutrient composition of plants:

$$X = f^{(S)} \text{ CL, T, P, M} \quad (2)$$

or even

$$X \propto f^{(K)} \text{ S, CL, T, P, M} \quad (3)$$

A comparison of soil from different sources when conducted in a single climate, as in the Neubauer test or by the Mitscherlich pot technique, would satisfy the requirement of equation (2). Similarly, a comparison of different levels of one particular nutrient of interest, when conducted in a single climate and a single soil, would satisfy the requirements of equation (3), as in Bray's field design, of which the data could be interpreted by using Bray's modified Mitscherlich equation (54).

2. Soil Analysis Contrasted with Plant Analysis

Though analysis of soils through chemical means is desirable or essential in solving some agronomic problems, nevertheless,

reliance solely on soil analysis for estimating nutrient requirements of crops is fraught with difficulties (54). These obstacles are clearly indicated in plant-nutrient equation (1). Under field conditions, for example, the soil is only one of the many factors determining the nutrient concentration within the plant. The analysis of the plant gives an integrated value of these and other factors which have influenced the nutrient concentration of the plant up to the time of sampling. By comparing the nutrient concentration observed within the plant with the corresponding critical nutrient levels of the crop, one can draw conclusions on which to base addition of fertilizers to soils according to the nutrient requirements of the crop (17, 33, 54).

3. Estimation of the Critical Nutrient Level

Estimation of the critical nutrient level for a crop under field conditions is primarily a matter of comparing the concentration of the nutrient in plants known to be deficient with those amply supplied with the given nutrient. Through a series of these determinations over a period of several years a positive correlation between yield and the concentration of the nutrient in the plant will be obtained. The critical nutrient level is at the point of concentration of the nutrient in the plant, above which no further yield response can be expected (17, 45). As reported by Tyler, et al. (51, 52, 53), the critical potassium levels for potatoes at different stages of plant

growth are summarized in the following table.

Per cent Potassium (K) in Petiole - Dry Weight Basis

<u>Age of Plant</u>	<u>Deficient</u>	<u>Intermediate</u>	<u>Sufficient</u>
Early season	9	9-11	11
Midseason	7	7 - 9	9
Late season	4	4 - 6	6

EXPERIMENTAL PROCEDURE

1963 Project

A. Field Plot Design

Field trials were conducted at three locations, viz., University Parkland Farm, Winterburn and Fort Saskatchewan. Three locations were selected to provide a good representation of typical potato soils in this area.

27-14-0 was applied at the rate of 440 pounds per acre, which is equivalent to 118.8 pounds of NO_3 and 61.6 pounds of P_2O_5 , to give adequate amounts of nitrogen and phosphate in the soil. Potash treatments were as follows:

		<u>KCL (0-0-60) grams/plot</u>					
<u>Treatment</u>		<u>Fort Saskatchewan</u>		<u>Winterburn</u>		<u>Parkland</u>	
<u>K_2O lb/acre</u>		<u>banded</u>	<u>b.c.*</u>	<u>banded</u>	<u>b.c.*</u>	<u>banded</u>	<u>b.c.*</u>
1.	0	0	0	0	0	0	0
2.	55	44.8	44.8	50	50	43	43
3.	110	89.6	89.6	100	100	86	86
4.	220	179.2	179.2	200	200	172	172
5.	330	268.8	268.8	300	300	258	258
6.	440	358.4	358.4	400	400	344	344

*broadcast

The same increments of potash were used in all three locations, while the actual amount of KCl applied was varied to correspond to the different widths of row at each location. Both 27-14-0 and KCl applications to each plot were split into two equal portions. The one portion was broadcast on the surface of the ground and worked into the soil with a rotovator; the other was banded two inches below and two inches to each side of the seed (2, 16). Treatments were replicated four times in a randomized block design.

Plots consisted of single rows 30 feet long and a single guard row alternated with each treated row. Fertilizer was not applied to the guard rows. The distance between rows was variable, three feet at Parkland, three and a half feet at Winterburn and 37.5 inches at Fort Saskatchewan. The variation in row width was to facilitate machine cultivation at each location.

Certified seed of the Netted Gem variety was used. Whole tubers weighing approximately 28 grams were used to avoid the possibility of contamination in cutting and to avoid the variation between apical and basal bud distribution (15). Seed tubers were planted by hand six inches deep one foot apart in the row. Planting dates were: Parkland, May 31; Winterburn, June 5; Fort Saskatchewan, June 7th. The plantings were 2 to 4 weeks later than general farm practice (27). Weeding and cultivating were done by the

farmers as part of their general practice.

Two of the four replications at Parkland were given supplemental irrigation. No irrigation was used at Winterburn or Fort Saskatchewan.

B. Soil Types

The Parkland farm soil was classified as Malmo silty clay loam (7). This soil was not particularly suitable for good production of high quality tubers. The soil often packed hard or became very sticky when wet.

The Winterburn soil used for this project was classified as Malmo silt loam (7) and had been used for potato growing under a 5 year rotation system consisting of two years of potato crop followed by one year of wheat, followed by another two years of barley or rye grass.

The Fort Saskatchewan soil was classified as Winterburn fine sandy loam (7), and used mainly for potato production with wheat, barley or rye grass grown for one year after every two to three years of potato crop. The land used for this trial had been planted to potatoes the preceding year. On the basis of soil texture, this was an ideal soil for potato production. Moisture fluctuation and insufficient nutrient supply prevented a good tuber yield.

C. Soil Tests (43)

1. General

Two groups of soil samples were taken from three fields involved and the amount of available NO_3 , P_2O_5 and K determined.

The first group of samples was collected before fertilizer application. The second group was taken approximately three weeks after fertilizers were applied. Results from these second samples were used as a check to assure that the available NO_3 and P_2O_5 were at an adequate level after fertilizer application. For the initial sampling four cores of soil to a depth of 6 inches were taken at random in each plot to provide a representative sample of the plot. The soil cores from the replicates for each treatment, a total of 16 cores, were combined, thoroughly mixed and 300 gram sample taken for analysis.

For the second sampling the four cores of soil per plot were taken in a manner such that each core alternated with the other on the two sides of the row of plants. The cores were taken 2 to 3 inches from the base of the plants. The second group of soil tests served to indicate the increase in available potassium in the soil subsequent to the applications of known quantities of K_2O , thus providing a basis for the study of the relationship between fertilizer application and the level of available potassium in the soil as

indicated by the soil test.

All samples were placed in a thermostatically controlled exhaust oven and dried at 65°C. The drying process was completed in the sample cartons used for collecting samples.

Each sample in its entirety was crushed to pass through a 2 mm sieve. This was accomplished by placing each sample in a ball mill type grinder with 2 mm stainless steel sieve attached to solid ends. The steel rollers inside the drum crushed the sample as it revolved and the sample fell into a collection tray.

2. Available Nitrate Determination

(a) Reagents (Diphenylamine solution and 0.025 N acetic acid)

Ten liters of extracting reagent (0.025 N acetic acid) were used, prepared by adding sufficient distilled water to 15.01 grams of 99.5% acetic acid to bring the solution up to volume. Diphenylamine solution was prepared by dissolving 0.03 gram of diphenylamine in 25 ml of concentrated sulfuric acid (nitrate free).

(b) Procedure

Five grams of crushed soil were measured into a 50 ml flask and 25 ml of extracting solution added rapidly. The contents of the flask were then shaken for 2 minutes and filtered, saving the

filtrate. If a clean filtrate was not obtained, the filtrate was refiltered till it was clear. To one drop of soil extract in a spot plate depression 8 drops of diphenylamine reagent were added. The mixture was rotated gently, allowed to stand for five minutes and read immediately by comparing the color with standard blue color charts. Results were recorded in pounds per acre available nitrate nitrogen.

3. Available Potassium Determination

Extraction procedure was the same as for nitrogen above.

The Flame Photometer (Baird Atomic DBY) was standardized in the following manner. The instrument was lighted 15 to 20 minutes before using. Three or four samples of distilled water were atomized through the instrument before beginning the analysis. A series of standard samples were prepared. Then equal volumes of standard solutions were mixed with equal volumes of a 100 ppm lithium solution. The instrument was balanced with the most concentrated standard. After recording the standard sample readings a curve was prepared. To 10 ml of soil extract 10 ml of 100 ppm lithium solution were added. After the solutions were mixed completely by a gentle shaking of the container, the potassium concentration was determined flame-photometrically. Results were recorded as pounds per acre of available potassium.

4. Available Phosphorus Determination

(a) Reagents

(i) Extracting Solution. (0.03 N ammonium fluoride in 0.03 N sulfuric acid). 38.5 grams of concentrated sulfuric acid were added to about 20 liters of distilled water. 27.7 grams of ammonium fluoride were dissolved in about 200 ml of distilled water. This fluoride solution was then filtered and added to the acid solution and made up to 25 liters with distilled water.

(ii) Nitric acid-vanadate-molybdate Solution. The nitric acid-vanadate-molybdate solution was prepared from two solutions, A and B, as follows. Solution A was prepared by dissolving 25 grams of ammonium molybdate in 400 ml of distilled water. Solution B was prepared by dissolving 1.25 grams of ammonium metavanadate in 300 ml of boiling distilled water. Solution A was poured into solution B after it had cooled to room temperature and was then made up to 1 liter with distilled water.

(iii) Standard Phosphorus Solution. 0.2195 grams of pure potassium dihydrogen phosphate were dissolved in distilled water and diluted to 1 liter. This solution contained 50 ppm of phosphorus. Appropriate standard solutions from

0.5 to 20 ppm were prepared from this stock solution.

(iv) Carbon Black. (G-ELF)

(b) Procedure

5-gram samples of crushed soil were measured into twelve 50 ml flasks; 0.5 teaspoonful of carbon black was added to each flask. 25 ml of extracting solution were dispensed into each flask rapidly and the flask shaken for 2 minutes. This solution was then filtered into graduated filter vials. Excess filtrate was siphoned off leaving 10 ml. After adding 10 ml of the vanadate-molybdate reagent the solution was allowed to stand for 15 minutes and the color development measured with a spectrophotometer. The results were recorded in pounds of available phosphorus per acre.

D. Plant Tissue Tests

1. Preparation of Samples

Petioles of the 4th leaf from the growing tip were used for tissue tests. One hundred petioles were collected from each plot and first washed with detergent water, then rinsed several times first with tap water and later with distilled water. Petioles were then cut into small pieces and air dried at 70°C for twenty-four hours in a thermostatically controlled exhaust oven.

After drying, the samples were put through a Wiley grinding mill, and ground to pass through a 40 mesh screen. Each sample was then stored in a small plastic bottle. Samples were taken on the following dates: Parkland, July 19-20, 1963; Fort Saskatchewan, August 7, 1963; Winterburn, August 8, 1963.

2. Potassium Determination

The extracting method used in this project was based on the fact that K and Na can be extracted directly from plant tissue with $2\text{ N NH}_4\text{OAC} - 0.2\text{ N Mg (OAC)}_2$ with the same recoveries of K and Na as those obtained by ashing the plant tissue. Extraction of the K and Na of organic residues gives the organically bound and the exchangeable forms of K and Na but appropriately excludes that in the extraneous mineral particles (36).

(a) Extracting solution ($2\text{ N NH}_4\text{OAC} - 0.2\text{ N Mg (OAC)}_2$):

925.032 grams of NH_4OAC and 128.6856 grams of Mg(OAC)_2 weighed, dissolved with distilled water, and brought up to 6 liters.

(b) Standard solution: 38.16 mg of dry KCl were dissolved in 200 ml of $2\text{ N NH}_4\text{(OAC)} - 0.2\text{ N Mg (OAC)}_2$ solution. This potassium stock solution with 100 ppm of K was then used to make a series of standard solutions by diluting with distilled water to the concentrations of 1, 2, 3, 4, 5, 10, 15, 20, and 30 ppm.

(c) Potassium Extraction: 0.5 gram of ground plant tissue was measured into a 150 ml flask and extracted with 100 ml of 2 N NH_4OAC - 0.2 N $\text{Mg}(\text{OAC})_2$ for one hour. This was done by fastening the stoppered flask on to an electrical shaker, set at medium speed.

The suspension was filtered. 10 ml of the filtrate was brought up to 200 ml with distilled water.

(d) Potassium Determination: The Flame Photometer (Baird Atomic DBY) was lighted and balanced as previously described for soil tests.

10 ml samples of diluted extract were mixed with 10 ml aliquots of lithium solution. Potassium was determined flame-photometrically. Results were recorded in per cent of potassium in dry weight material.

E. Yield Tests

Harvesting was done in early October, 1963. Tubers of 25 hills in each treated row were dug out with a fork. The tubers were then stored at 40°F for about five months. After storage the tubers were graded into No. 1's, No. 2's and culls.

Specific gravity of tubers was determined by a known

concentration salt water float-sink method (25). This was done on June 19th, 1964.

The amounts of table salt per gallon of water corresponding to various specific gravities at which each tuber was tested were as follows:

<u>Specific Gravity</u>	<u>Table Salt, per Gallon of Water Grams</u>	<u>Mealiness of Cooked Potatoes</u>
1.050	282	Soggy
1.060	340	Soggy
1.070	397	Fairly mealy
1.080	455	Fairly mealy
1.090	512	Mealy
1.100	524	Very mealy

The solutions were checked by a Densitometer to assure proper specific gravity of each solution. Five tubers from each plot were tested. The specific gravity of a tuber was considered to be that of the salt solution in which it would barely float.

1964 Project

The 1964 trials were conducted at the same locations as in the preceding year. A few modifications were made in the 1963 procedure for more precise results.

A. Field Plot Design

500 pounds per acre of 16-20-0 were applied to provide 80 pounds of NO_3 and 100 pounds of P_2O_5 to the soil. Five increment applications of K_2O were used as treatments in a 5 x 5 Latin Square field design. The size of treatment unit was doubled as compared to that of the 1963 project. Each unit contained two 25-foot rows; one guard row separated each unit. The treatments were as follows:

Treatment <u>K_2O lb/acre</u>	<u>KCl grams per plot</u>		<u>Parkland</u>
	<u>Fort Saskatchewan</u>	<u>Winterburn</u>	
0	0	0	0
120	326.0	362.9	362.9
180	489.0	544.3	544.3
240	652.0	728.6	728.6
300	815.0	910.0	910.0

Fertilizers were broadcast on the surface of the plot and incorporated into the top 6 inches of soil with a rotovator.

Seed tubers were prepared by the same procedure as in 1963 and planted 4 inches deep, one foot apart in the row. The distances between rows were: 42 inches at Parkland and Winterburn, and 37.5 inches at Fort Saskatchewan. Planting dates were: Parkland, May 27; Winterburn, May 28; Fort Saskatchewan, June 3rd.

B. Soil Types

The soil of the Parkland plot in 1964 was similar to that of the preceding year, and was classified as Malmo silty clay loam (12). The Winterburn soil was classified (12) as Winterburn loam which is lighter than the soil used for the 1963 trial. The crop of the preceding year in this Winterburn location was potato. Fort Saskatchewan soil was classified as Winterburn fine sandy loam (12). The preceding crop was rye grass and legume.

C. Soil Tests

Three groups of soil samples were taken in this project. The first group was taken before fertilizer application, the second three weeks after fertilization to study the increases in available nitrogen, phosphorus and potassium and the third at harvest time to determine the available nutrient levels after one season of cropping.

The samples were collected and prepared as described

previously for the 1963 tests. Available nitrogen, phosphorus and potassium were determined using the same procedures as in 1963.

D. Plant Tissue Tests

Plant tissue samples were collected in the same manner as the preceding year. The procedures used for washing, drying, grinding, and potassium determination were the same as in 1963.

Potato leaf petiole samples were taken at the following dates: Fort Saskatchewan, July 29; Winterburn, July 28; Parkland, July 27th.

E. Yield Tests

Potato tubers were dug with a mechanical digger with a mobile belt attached to screen out the dirt. The tubers were spread on the surface of the ground and then picked by hand. This was done in early October.

The grading of tubers into No. 1's, No. 2's and culls was done immediately after harvesting. The specific gravity of tubers was determined using the same methods as in 1963. This was done on November 6th to November 8th.

RESULTS

I. SOIL TESTS

A. 1963

The results of laboratory determinations of nutrient levels, pH, and salt content of the soil samples, taken from 1963 trial plots, are given in Table I.

Each determination includes two readings indicated under a. and b. in the table. Results listed in the columns under a. were taken before fertilizer application, results in the columns under b. were taken three weeks after fertilizer application. In this table as in succeeding ones the ditto signs (") and the actual figures above them represent pooled samples.

As shown in Table I, under A) for Fort Saskatchewan, B) for Winterburn, and C) for Parkland, the nitrate nitrogen levels and the phosphate levels in the soil were increased with the application of 118.8 lb per acre of NO_3 and 61.6 lb per acre of P_2O_5 . Since half of these amounts of fertilizer were banded 2 inches below and 2 inches to the sides of the seed pieces, the soil samples may have included portions of these banded areas. This sampling error may account for the variation in available NO_3 and P levels among the plots within a relatively small area at each location.

Table I. Soil Test Values Before and After Fertilizer Applications, 1963

Treatment Number	lb/acre K ₂ O	lb/acre Available Nutrients						Soil			
		<hr/>						Reaction		Conductivity	
		NO ₃ *		P*		K		(pH)		(mmhos)	
		a	b	a	b	a	b	a	b	a	b
A. Fort Saskatchewan											
1	0	27	135	57	58	136	132	6.5	5.7	0.8	2.0
2	55	"	135	"	59	"	160	"	5.8	"	1.9
3	110	"	157	"	59	"	216	"	5.7	"	2.6
4	220	"	180	"	58	"	252	"	5.6	"	2.8
5	330	"	202	μ	42	"	342	"	5.7	"	2.6
6	440	"	202	"	60	"	540	"	5.6	"	4.0
B. Winterburn											
1	0	52	180	26	46	70	102	6.3	6.0	0.7	2.0
2	55	"	191	"	35	"	120	"	6.0	"	1.8
3	110	"	191	"	54	"	178	"	6.1	"	2.2
4	220	"	214	"	59	"	262	"	6.1	"	3.2
5	330	"	180	"	39	"	274	"	5.7	"	3.2
6	440	"	202	"	39	"	428	"	5.9	"	3.8
C. Parkland											
1	0	67	225	33	37	118	104	5.6	5.3	0.9	2.2
2	55	"	180	"	32	"	120	"	5.3	"	2.0
3	110	"	202	"	35	"	148	"	5.4	"	2.4
4	220	"	270	"	34	"	186	"	5.2	"	2.6
5	330	"	247	"	36	"	200	"	5.3	"	2.8
6	440	"	270	"	37	"	360	"	5.2	"	4.0

* 118.8 lb/acre of NO₃ and 61.6 lb/acre of P₂O₅ were applied to each plot.

a - before fertilization, b - after fertilization, " - from one pooled sample.

Three weeks after the fertilizer application the exchangeable potassium level of the soil in each plot was increased in response to the potash application. Linear correlation coefficients and regression coefficients of y on x, expressed by the equation $y = a + bx$, (47) were used as a means to evaluate the relation between the exchangeable potassium of the soil and potash application. The correlation coefficient (r_{xy}) and the regression coefficient (b_{xy}) were calculated from the data with the following equations.

$$r_{xy} = \frac{\sum xy - \sum x \sum y / n}{\sqrt{(\sum x^2 - \frac{(\sum x)^2}{n}) (\sum y^2 - \frac{(\sum y)^2}{n})}} \quad (1)$$

$$b_{xy} = \frac{\sum xy - \sum x \sum y / n}{\sum x^2 - (\sum x)^2 / n} \quad (2)$$

The calculated coefficients were as follows.

Relationship between Exchangeable Potassium of the soil and
the Increment Rate of Potash Application

<u>Location</u>	<u>Correlation Coefficient</u>	<u>Regression Coefficient</u>
Fort Saskatchewan	+0.98**	0.85
Winterburn	+0.98**	0.70
Parkland	+0.93**	0.51

** Significance exceeds 0.01 level.

The correlation coefficient between soil exchangeable potassium and potash application of each of the three locations was positive and significant at the 0.01 level. Inspection of the regression coefficients listed above and the regression lines in Fig. 1, shows that the response to potash application was greatest at Fort Saskatchewan (Winterburn fine sandy loam), less at Winterburn Malmo silt loam, and the least at Parkland (Malmo Silty clay loam). These would indicate that each soil had a different potassium fixing power or buffering effect.

It is interesting that the soil pH values were slightly lower, whereas the salt content values, listed under conductivity in Table I, were considerably increased three weeks after fertilizer application. In all three locations, the plot that received the highest amount of fertilizer showed an unfavorable level of salts. No significant influence on soil sulphate content was observed.

B. 1964

The results of laboratory determinations of nutrient levels, pH and salt content of the soil samples, taken from the 1964 trial plots, are presented in Table II. The results from the Fort Saskatchewan trial are given in section A of the table, the Winterburn trial in section B and the Parkland trial in section C.

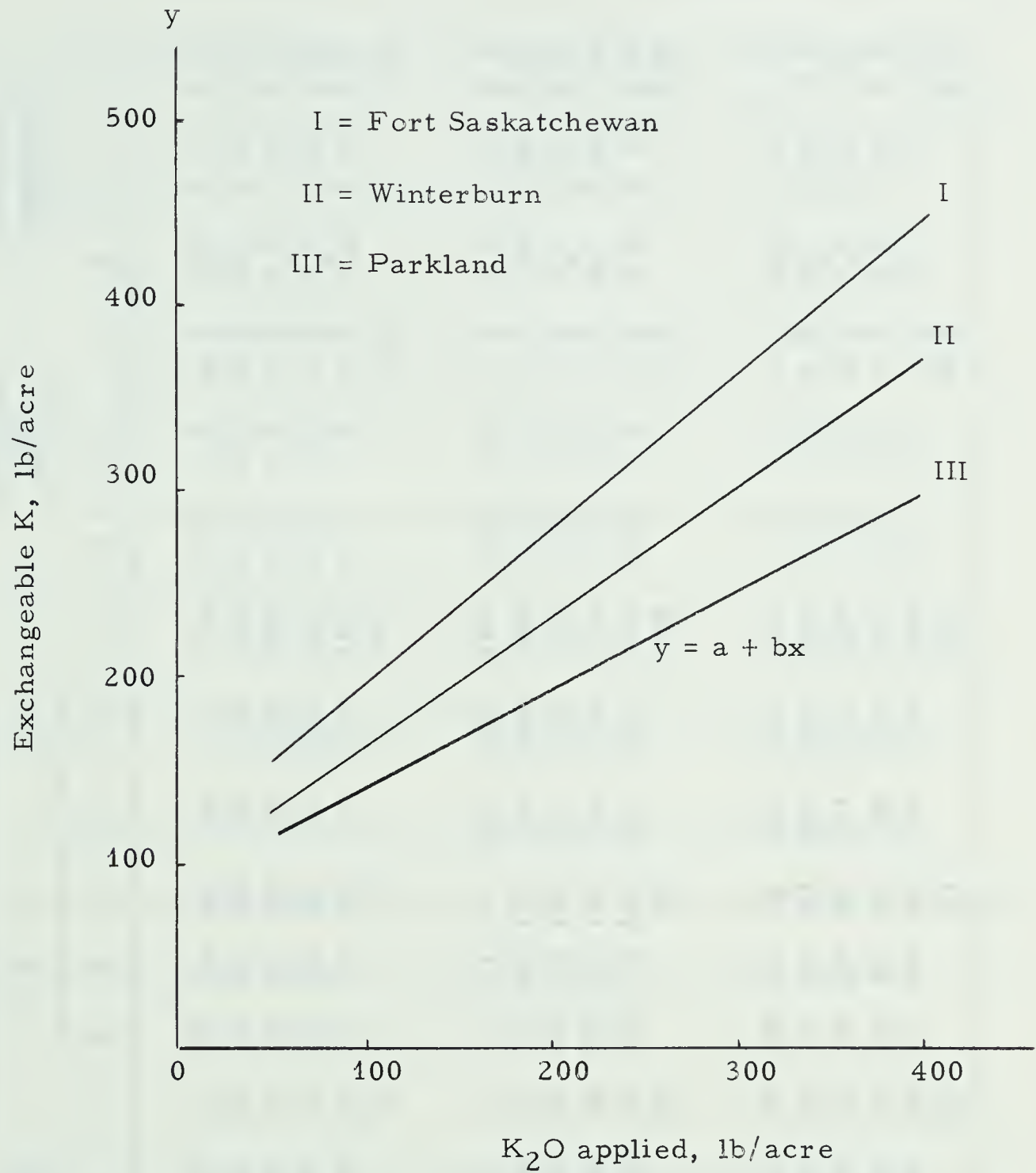


Fig. 1. Relation of exchangeable K in soil to 6 rates of K₂O application (1963).

Table II. Soil Values Before, After Fertilizer Application, and at Harvest, 1964.

Treatment Number	lb/acre K ₂ O	lb/acre Available Nutrients									Soil Reaction (pH)			Conductivity (mmhos)			
		NO ₃			P			K			a	b	c	a	b	c	
		a	b	c	a	b	c	a	b	c							
A. Fort Saskatchewan																	
1	0	45	100	21	20	54	44	74	70	58	6.3	6.0	6.1	0.5	1.5	0.6	0.6
2	120	67	108	27	22	59	60	62	110	86	6.2	5.9	5.9	0.7	2.0	0.7	0.7
3	180	67	100	19	21	57	58	76	138	106	6.1	5.9	5.9	0.6	2.0	0.6	0.6
4	240	45	100	16	23	63	63	60	232	120	6.2	5.9	5.9	0.5	2.4	0.6	0.6
5	300	79	100	47	23	75	70	70	268	152	6.2	5.8	5.7	0.6	3.0	1.0	1.0
G.R.				16			22			50			6.2			0.5	0.5
B. Winterburn																	
1	0	79	97	22	92	127	112	124	140	100	5.8	5.7	5.7	0.8	1.6	0.7	0.7
2	120	85	100	27	92	120	127	130	180	148	5.8	5.6	5.7	0.8	2.0	0.9	0.9
3	180	85	100	20	95	120	129	132	196	124	5.8	5.5	5.5	0.9	2.4	0.8	0.8
4	240	67	100	90	90	130	120	114	220	158	5.8	5.6	5.5	0.7	2.4	1.4	1.4
5	300	79	100	18	89	135	117	130	244	160	5.8	5.5	5.6	0.8	0.3	0.8	0.8
G.R.				25			99			138			5.8			0.7	0.7
C. Parkland																	
1	0	45	135	70	28	54	46	100	124	103	5.5	5.4	5.3	0.6	1.4	1.0	1.0
2	120	50	155	74	27	56	43	106	174	125	5.5	5.3	5.4	0.7	1.6	1.1	1.1
3	180	48	124	61	26	60	41	101	172	130	5.5	5.3	5.3	0.6	2.2	1.2	1.2
4	240	47	159	68	25	52	44	98	205	162	5.5	5.3	5.3	0.6	2.4	1.3	1.3
5	300	60	100	70	25	49	47	102	232	170	5.5	5.3	5.3	0.7	2.2	1.3	1.3
G.R.				29			31			122			5.5			0.6	0.6

G.R. = Guard row

a - before fertilization, b - after fertilization, c - at harvest

Each determination includes three readings indicated under column headings a, b, and c in the table. Results listed in the columns lettered a, were taken before fertilizer application, those listed in the columns lettered b, were taken three weeks after fertilizer application, those at the time of harvest in the columns lettered c. Results from soil samples, taken from the guard rows at the time of harvest are included under the heading G. R.

The nitrate nitrogen and phosphate levels of the soil were increased with an application of 80 lb.per acre of NO_3 and 100 lb. per acre of P_2O_5 . The exchangeable potassium level of each plot was increased in response to each increment of potash application.

The correlation coefficient and regression coefficient between exchangeable potassium and potash application were calculated with the same equations as used for the 1963 soil data. These coefficients are listed as follows.

Relationship Between Soil Exchangeable Potassium and the
Increment Rate of Potash Application

<u>Location</u>	<u>Correlation Coefficient</u>	<u>Regression Coefficient</u>
Fort Saskatchewan	+0.95**	0.689
Winterburn	+0.97**	0.315
Parkland	+0.62 n.s.	0.342

** - Significance exceeds 0.01 level, n.s. - not significant

There were significant positive correlations at 0.01 level between soil exchangeable potassium and potash application at Fort Saskatchewan and Winterburn. The correlation coefficient calculated for Parkland soil was not significant.

As shown in Table II and Figure 2 the potash application increased the exchangeable potassium of the soil to a greater degree at Fort Saskatchewan (Winterburn fine sandy loam), than at either of the other locations demonstrating a lower potassium fixing power in the Winterburn fine sandy loam.

Results of the third group of soil samples, taken at the time of harvest, showed that after one season of potato cropping the available nitrate nitrogen of the soil had been depleted to a much greater degree at Fort Saskatchewan and Winterburn than at Parkland. Inspection of the soil exchangeable potassium values of the check plots which received no potash showed the following trends.

1. A depletion of 20 lb per acre of available potassium was observed at harvest time on Fort Saskatchewan and Winterburn check plots. This depletion was not found in Parkland check plots.
2. Winterburn and Parkland check plot available potassium levels increased approximately 25 lb per acre within three weeks (in early June, 1964), the interval between the first and second soil sampling, indicating that the potassium of these soils was being released from the non-exchangeable form to exchangeable

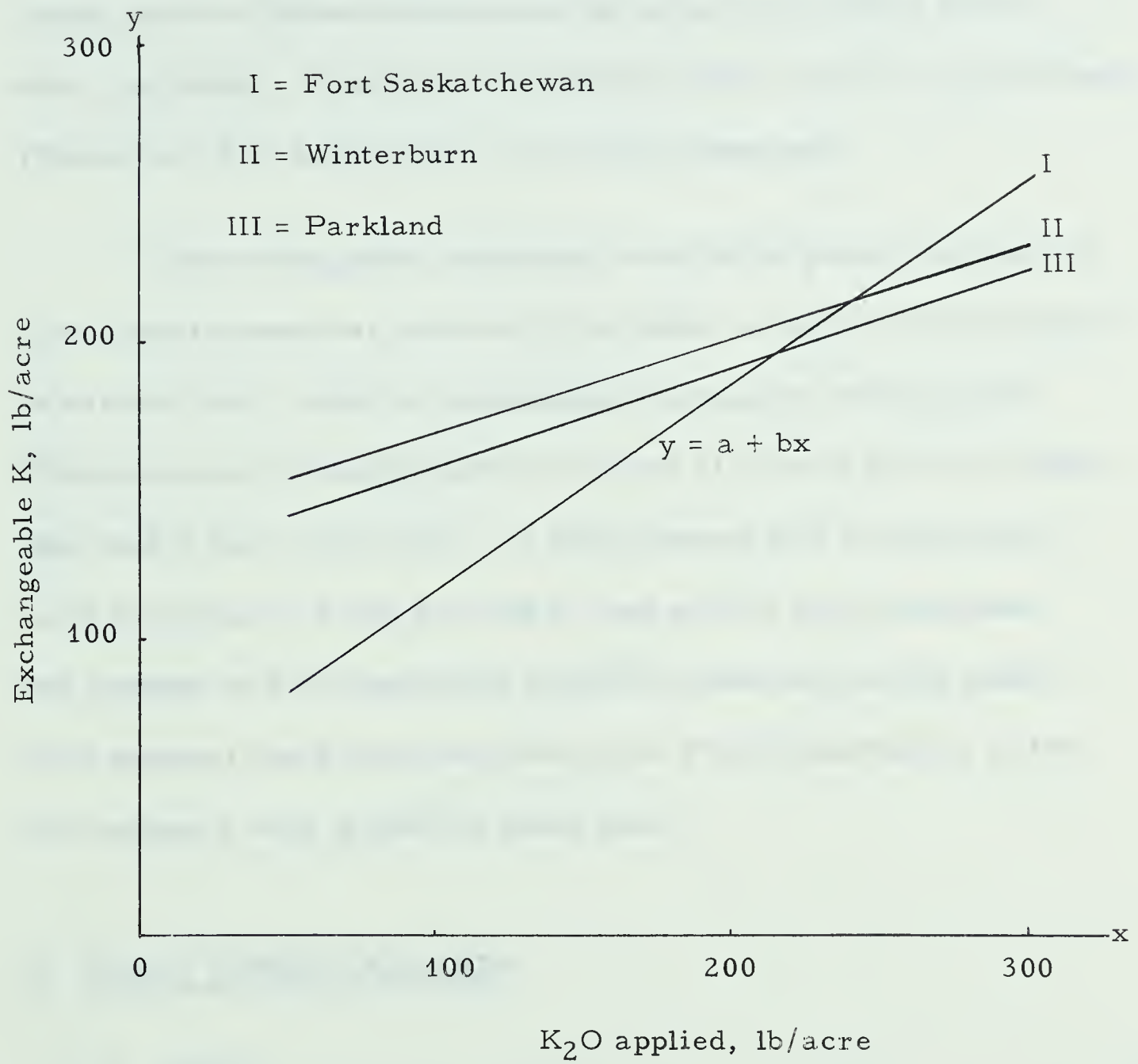


Fig. 2. Relation of exchangeable K in soil to 5 rates of K_2O application (1964).

form. This was not observed at Fort Saskatchewan.

These evidences would suggest that the magnitude of nutrient supply power of these soils were in the order of Parkland (Malmo silty clay loam), Winterburn (Winterburn loam), and Fort Saskatchewan (Winterburn fine sandy loam), as would be expected.

The exchangeable potassium level of the guard row areas at Fort Saskatchewan was practically the same as that of the check plots at harvest time, while the exchangeable potassium levels of the Winterburn and Parkland guard row areas at harvest time was higher than that of their check plots. It might appear that the application of 80 lb. per acre of NO_3 and 100 lb. per acre of P_2O_5 facilitated the removal of more potassium from the check plots by the plants. This removal could have been reduced at Fort Saskatchewan by the low moisture level of the fine sandy loam.

II. PLANT TISSUE ANALYSES

A. 1963

The amount of potassium in plant tissue was increased upon fertilizer application as revealed by plant tissue analyses. The laboratory determination values of the total amount of potassium in plant samples of 1963 trials are given in Table III, in terms of percentage potassium in oven-dried potato leaf petioles.

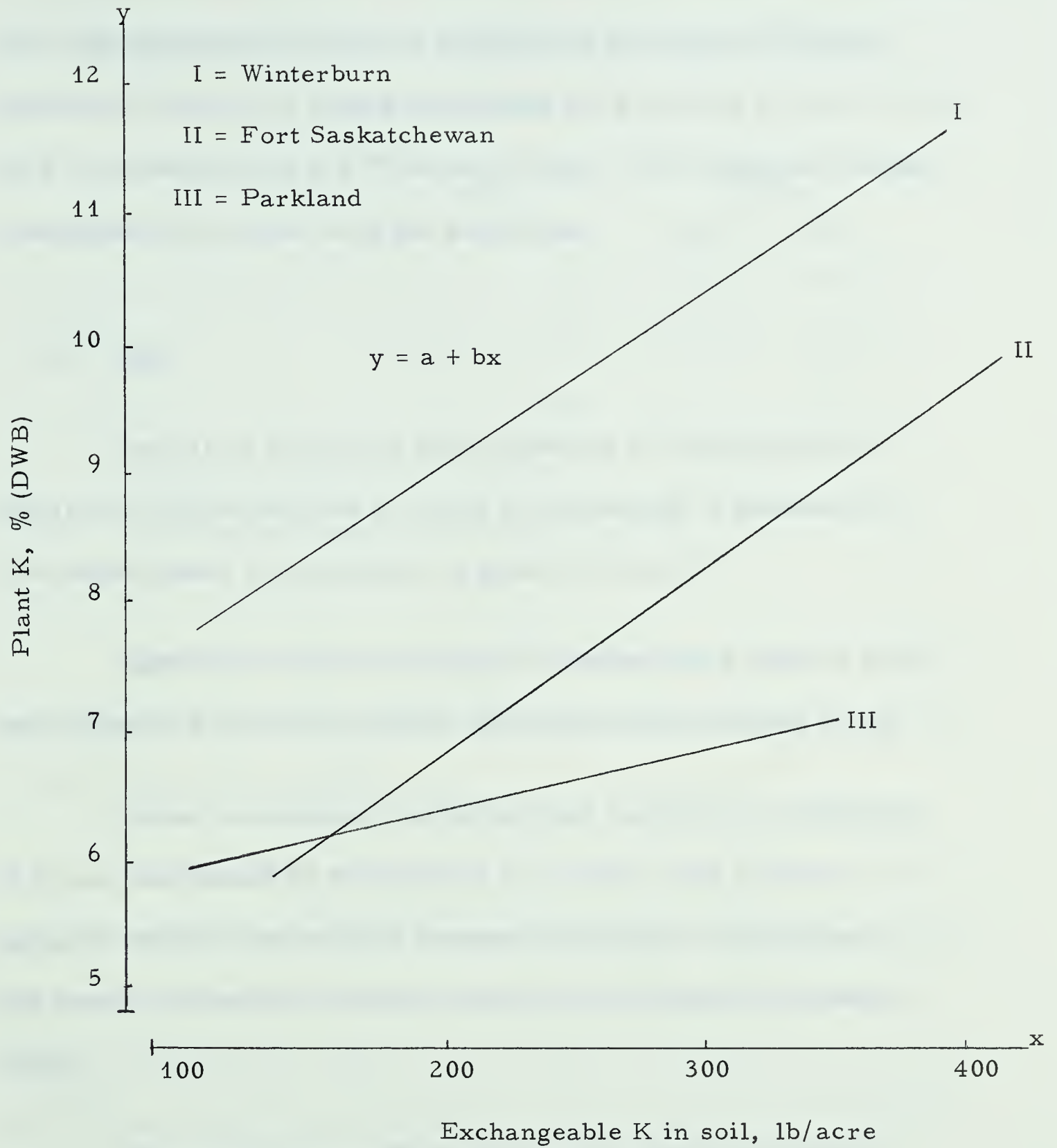


Fig. 3. Relation of percentage K (DWB) in potato leaf petioles at mid-season to exchangeable K in soil (1963).

Tissue data from these experiments were analysed statistically with interpretations of levels of significance by means of F ratios. Significant differences among treatments were found at a level of 0.05 for Fort Saskatchewan and Winterburn trials. The difference among treatments at Parkland were not significant.

B. 1964

Results of laboratory determinations of total amounts of potassium in plant samples in terms of percentage of potassium in oven-dried potato leaf petioles are given in Table IV.

Significant differences among treatments at a level of 0.05 were found in Fort Saskatchewan, Winterburn and Parkland trials.

Linear correlation coefficients and regression coefficients of y on x, expressed by the equation $y = a + bx$, were used as a means to evaluate the relation between percentage of potassium in dry potato leaf petioles at mid-season and exchangeable potassium levels.

The correlation coefficient (r) and regression coefficient (b) were calculated with the same equations as used for soil data. The calculated coefficients are as follows:

Relationship Between Percentage Potassium in Potato Leaf

Petioles at Midseason (Dry Weight Basis) and Available

Potassium Levels

<u>Location</u>	<u>1963</u>		<u>1964</u>	
	<u>r_{xy}</u>	<u>b_{xy}</u>	<u>r_{xy}</u>	<u>b_{xy}</u>
Fort Saskatchewan	+0.91*	0.0138	+0.89*	0.0212
Winterburn	+0.92**	0.0133	+0.97**	0.0295
Parkland	+0.94**	0.0044	+0.95*	0.0117

* - Significance exceeds 0.05 level

** - Significance exceeds 0.01 level

Significant positive correlations were found between percentage potassium in plants and soil exchangeable potassium at three locations in both years (1963 - 1964).

Comparing the slope of the regression lines in Fig. 3 and 4., it is interesting to note that the rate of increase in potassium concentration in potato leaf petioles at mid-season (D. W. B.) in response to potash application was higher on loam soil at Winterburn than either on light sandy loam at Fort Saskatchewan or on clay loam at Parkland in both years.

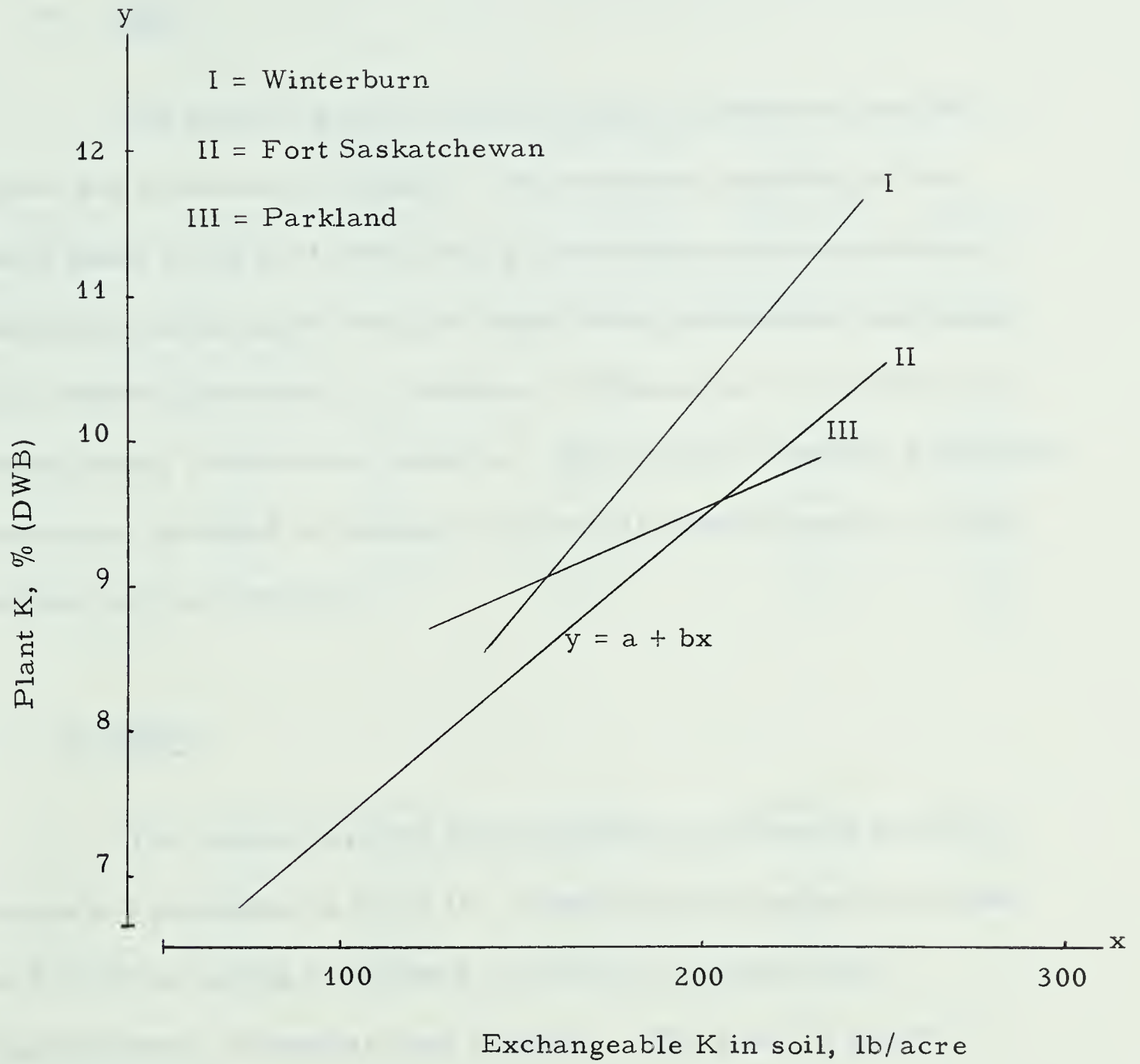


Fig. 4. Relation of percentage K (DWB) in potato leaf petioles at mid-season to exchangeable K in soil (1964).

III. SPECIFIC GRAVITY OF TUBERS

A. 1963

The specific gravity determinations of tubers in the 1963 trials are presented in Table III. Decreases in specific gravity were found at the 0.01 level among Fort Saskatchewan treatments. Significant differences were not found among treatments (increment rate potash application) at Parkland. Differences at 0.01 level were found among replications, however. Since tubers from the Winterburn trial were damaged in storage, data for the specific gravity of these tubers were not obtained.

B. 1964

The specific gravity determinations of tubers in the 1964 trials are presented in Table IV. Significant decreases were found at 0.01 level among treatments at all three locations, Fort Saskatchewan, Winterburn and Parkland. The specific gravity of the tubers of the guard rows was included as a treatment in the statistical analyses.

Table III. Effect of Different Rates of Potash Application on Tuber Yield, Potassium Content in Plant Tissue and Specific Gravity of Tubers, 1963.

Treatment Number	lb/acre K ₂ O	Soil Test lb/acre Available K	Tissue Test Percentage K in Tissue (D. W. B.)	Yield Field Run (tons/acre)	Specific Gravity
A. Fort Saskatchewan					
1	0	132	4.2	9.0 a	1.097
2	55	160	6.9	10.1 b	1.095
3	110	216	7.5	10.3 b	1.087
4	220	252	8.3	10.9 b	1.084
5	330	342	9.3	11.1 b	1.087
6	440	540	10.9	10.4 b	1.082
G.R.*					1.099
B. Winterburn					
1	0	102	7.2	10.5	
2	55	120	7.6	10.8	
3	110	178	9.1	12.1	
4	220	262	10.6	11.1	
5	330	274	10.8	12.3	
6	440	428	11.3	11.5	
C. Parkland					
1	0	104	6.1	18.1	1.093
2	55	120	6.0	19.4	1.094
3	110	148	6.1	18.3	1.090
4	220	186	6.2	17.7	1.091
5	330	200	6.6	21.5	1.088
6	440	360	7.1	17.5	1.092
G.R.*					1.091

a, b, - Significantly different at 0.05 level.

* - Guard row, no fertilizer was applied.

Table IV. Effect of Different Rates of Potash Application on Tuber Yield, Potassium Content in Plant Tissue, and Specific Gravities of Tubers, 1964.

Treatment Number	lb/acre K ₂ O	Soil Test lb/acre Available K	Tissue Test Percentage K in Tissue (D. W. B.)	Yield Field Run (tons/acre)	Specific Gravity
A. Fort Saskatchewan					
1	0	70	5.8	7.8 a	1.086
2	120	110	8.1	9.8 b	1.082
3	180	138	9.4	10.0 c	1.080
4	240	232	10.0	9.5 b	1.068
5	300	268	10.6	10.4 d	1.072
G. R.				6.9	1.092
B. Winterburn					
1	0	140	8.5	13.2 a	1.092
2	120	180	9.6	13.6 b	1.086
3	180	196	10.4	13.9 b	1.082
4	240	220	10.8	14.2 b	1.085
5	300	244	11.4	14.3 b	1.080
G. R.				11.5	1.096
C. Parkland					
1	0	124.4	8.8	20.0	1.090
2	120	174.4	9.5	20.7	1.085
3	180	172.4	9.1	20.0	1.085
4	240	204.8	9.8	20.4	1.077
5	300	232.4	10.0	21.1	1.078
G. R.				12.8	1.085

a, b, c, d, - Significantly different at 0.01 level

a, b, (B) - Significantly different at 0.05 level

G. R. - Guard row, no fertilizer applied

IV. TUBER YIELDS

A. 1963

The yields of field run tubers in the 1963 trials are presented in Table III, under A), for Fort Saskatchewan, B), for Winterburn, and C), for Parkland.

The yield data were analysed statistically with interpretations of levels of significance by means of F ratios. When differences among treatments were found to be significant, Duncan's multiple range test method was used for comparison of means (47).

In 1963, significant differences at a level of 0.01 were found among treatments at Fort Saskatchewan. No significant differences were found among Winterburn treatments. Sprinkler irrigation applied to two of the four Parkland replications resulted in a highly significant interaction between water and application of potash.

B. 1964

The yields of field run tubers in 1964 are presented in Table IV. Significant differences among treatments at a level of 0.01 were found in the Fort Saskatchewan plots, and at 0.05 level in the Winterburn trial. Significant differences were not found in Parkland plots.

Linear correlation coefficients (r_{xy}) and regression coefficients

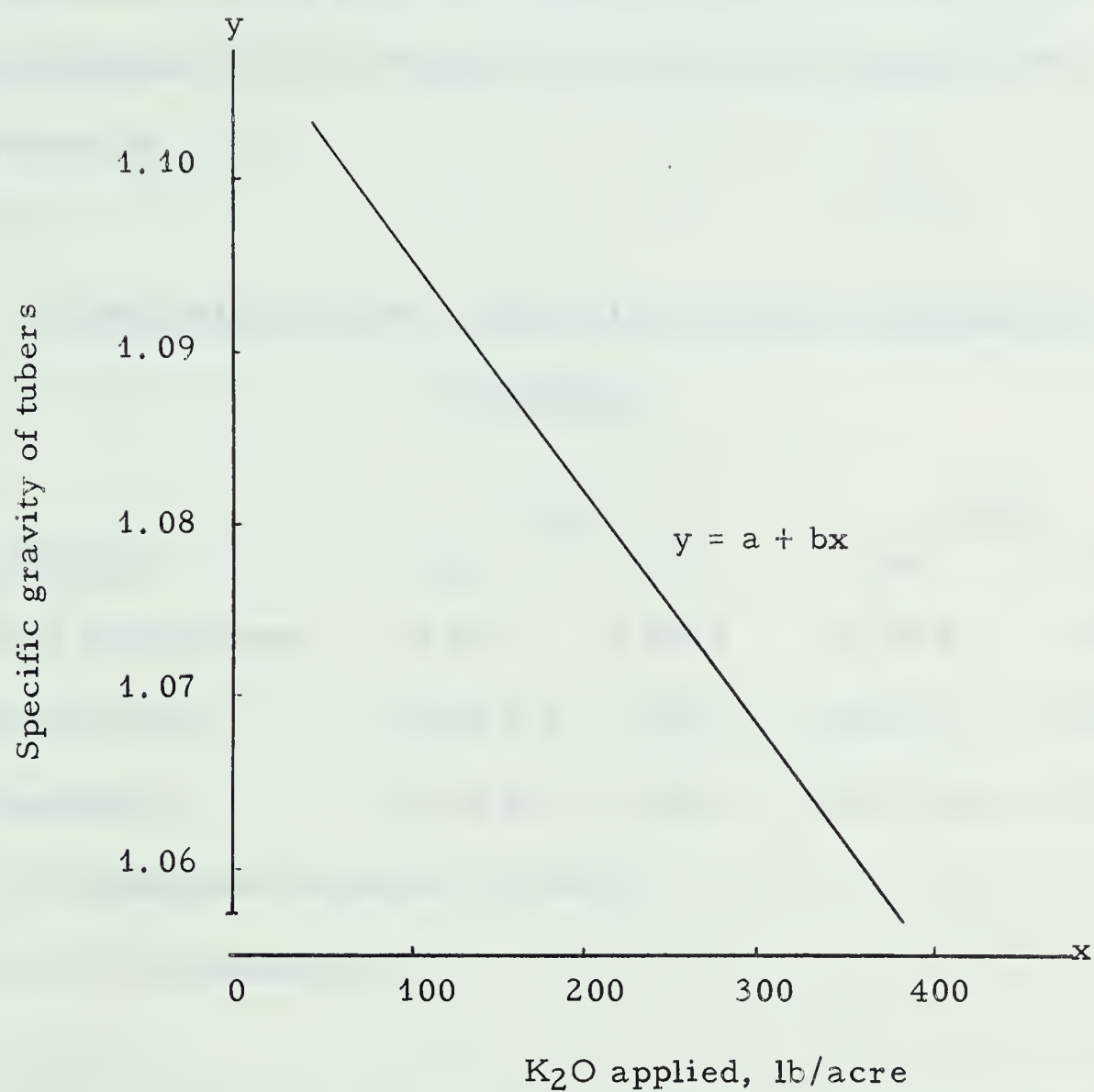


Fig. 5. Relation of specific gravity of potato tubers to K₂O application (1963 - 1964).

(b_{xy}), calculated by means of the same equations as mentioned previously for soil data, are listed as follows to evaluate the relationship between potato tuber yield and soil exchangeable potassium.

Relationship Between Tuber Yield and Soil Exchangeable

Potassium

<u>Location</u>	<u>1963</u>		<u>1964</u>	
	<u>r_{xy}</u>	<u>b_{xy}</u>	<u>r_{xy}</u>	<u>b_{xy}</u>
Fort Saskatchewan	+0.88*	0.0091	+0.70 n. s.	0.008
Winterburn	+0.68 n. s.	0.0067	+0.93*	0.0112
Parkland	+0.43 n. s.	0.0157	+0.75 n. s.	0.0090

* - Significance exceeds 0.05 level

n. s. - Not significant

Significant positive correlations were found in Fort Saskatchewan plots in 1963 and in Winterburn in 1964. The correlation found at Winterburn plots in 1963, Fort Saskatchewan in 1964 and Parkland in 1963 and 1964 did not reach the significant level.

Such analyses applied to potato tuber yield and percentage of potassium in potato petioles at mid-season (D. W. B.) indicate the following:

Relation Between Tuber Yield and K% in Leaf Petioles (D. W. B.)

<u>Location</u>	<u>1963</u>		<u>1964</u>	
	<u>r_{xy}</u>	<u>b_{xy}</u>	<u>r_{xy}</u>	<u>b_{xy}</u>
Fort Saskatchewan	+0.99**	0.44	+0.90*	0.452
Winterburn	+0.80 n. s.	0.52	+0.99**	0.391
Parkland			+0.55 n. s.	0.536

* - Significance exceeds 0.05 level

** - Significance exceeds 0.01 level

n. s. - Not significant

Significant positive correlations between tuber yield and potassium in plants were found in Fort Saskatchewan plots in both years. Significant positive correlation at the 0.01 level was found in Winterburn plots in 1964. Comparing the correlation coefficients listed above, it would appear that the potato tuber yield correlated better with the plant tissue test results than with the soil test results.

The relationship between tuber yield and potassium percentage in the plant, found in 1963 and 1964 trials is illustrated in Fig. 6 and Fig. 7.

The relationship between tuber yield and potash application is expressed by Willcox's Standard Yield Diagram. The relationship between tuber yield and soil exchangeable potassium level can be described by means of Bray's modification of Mitscherlich equation.

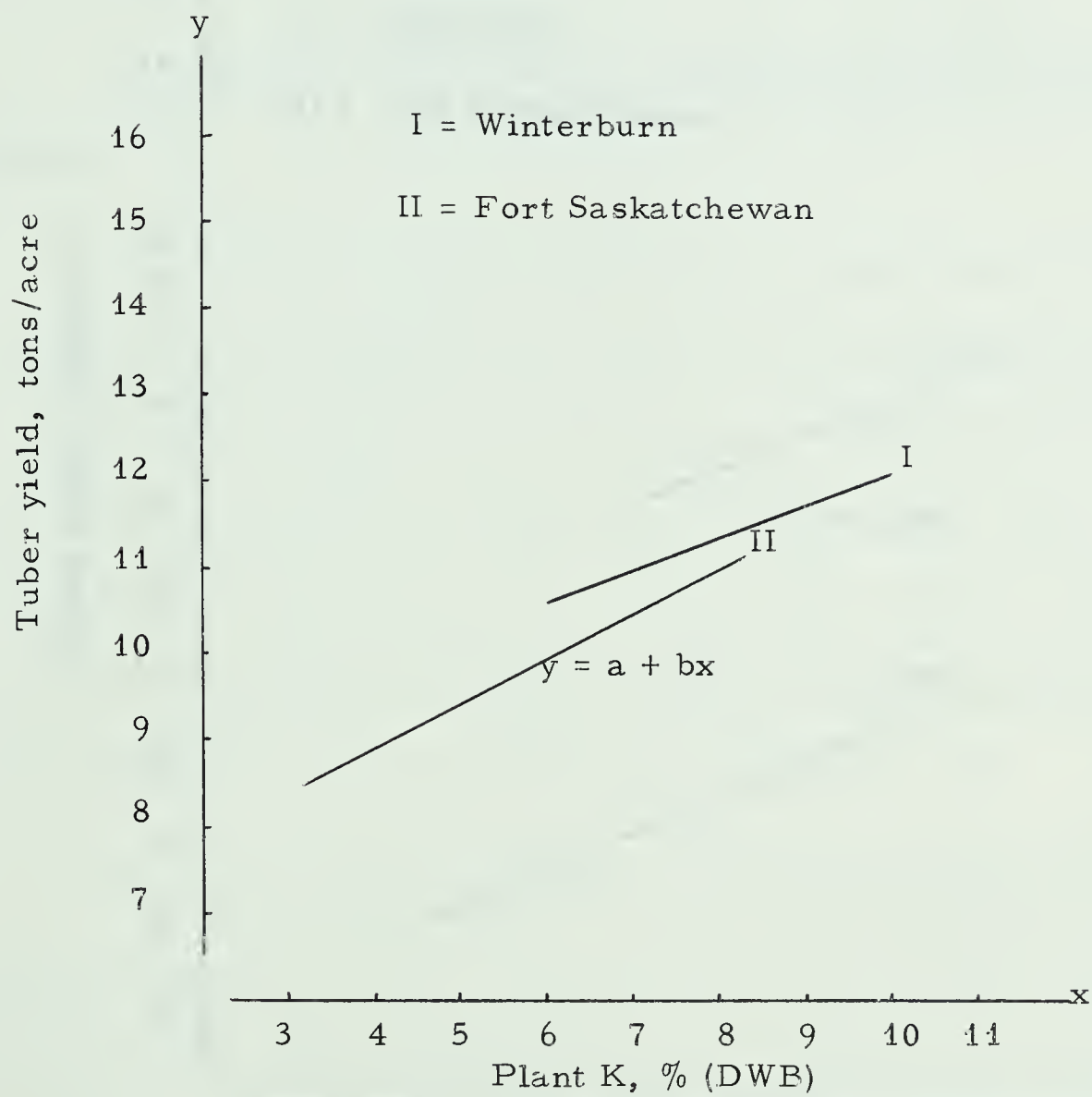


Fig. 6. Relation of tuber yield to percentage K (DWB) in potato leaf petioles at mid-season (1963).

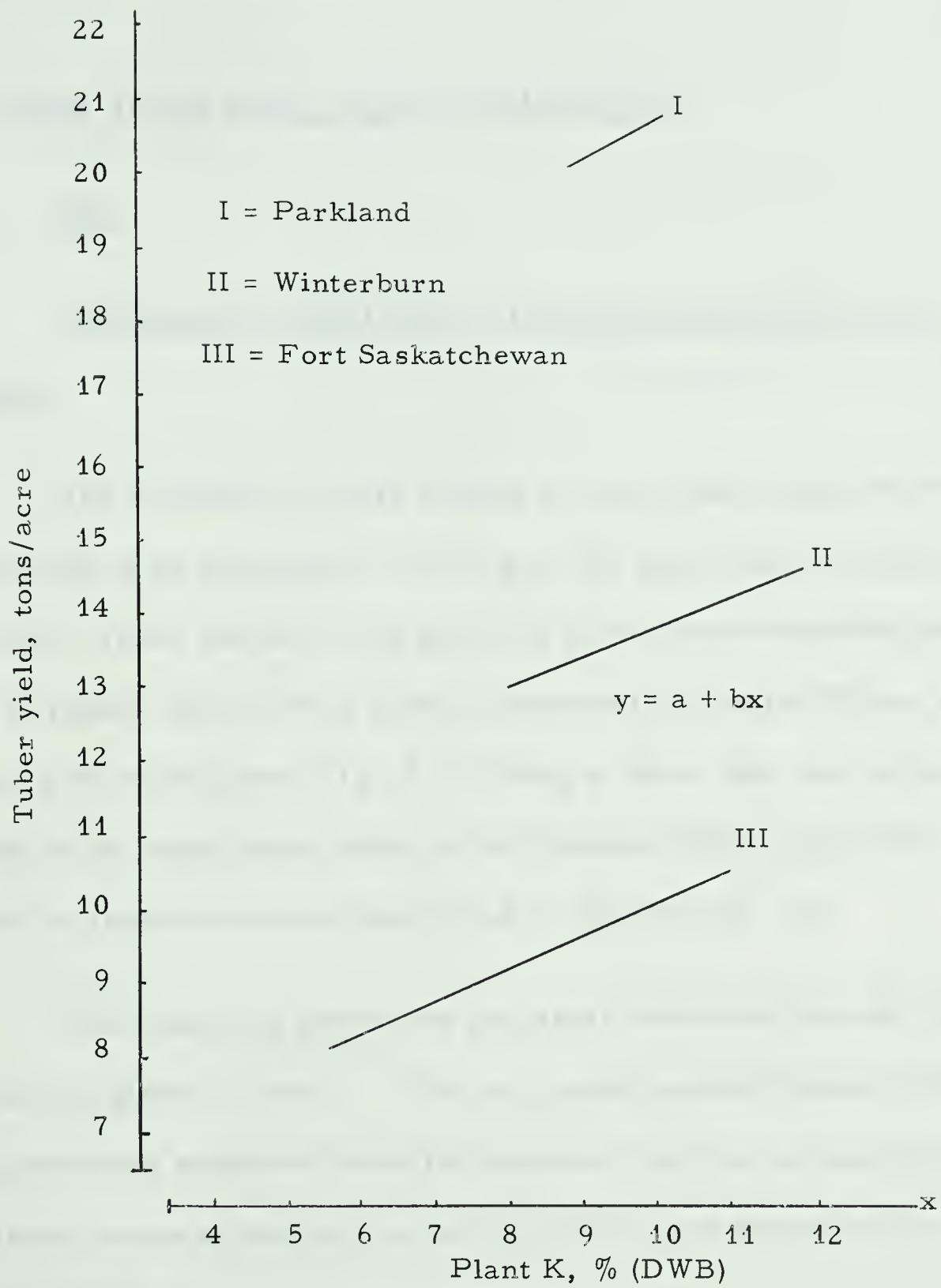


Fig. 7. Relation of tuber yield to percentage K (DWB) in potato leaf petioles at mid-season (1964).

These are given in later sections.

V. TUBER YIELD AND POTASH APPLICATION

A. 1963

The Standard Yield Diagram (Mitscherlich-Baule-Willcox System).

The amounts of potash applied in 1963 trials were divided by the term of 76 pounds per acre to give the baule units of potash per acre. Tuber yields in tons per acre and the corresponding baule units of potash applied were used in Mitscherlich-Baule-Willcox's Standard Yield Diagram (Fig. 8). Fitting of these data to a proper section of the logarithmic curve in the diagram were done by the method of approximation as described by Willcox (56, 57).

The empirical yields and the yields estimated through this system are given in Table V. The soil potash content before fertilizer application was estimated from the diagram, and the exchangeable potassium levels of the soils as determined by soil tests are also listed in Table V.

The yield calculated and the yields found were taken as paired data for the t test. The t values found were smaller than the tabulated t value for significance at 0.1 level indicating there is no

General Yield
Diagram (0 -
8 Baules)

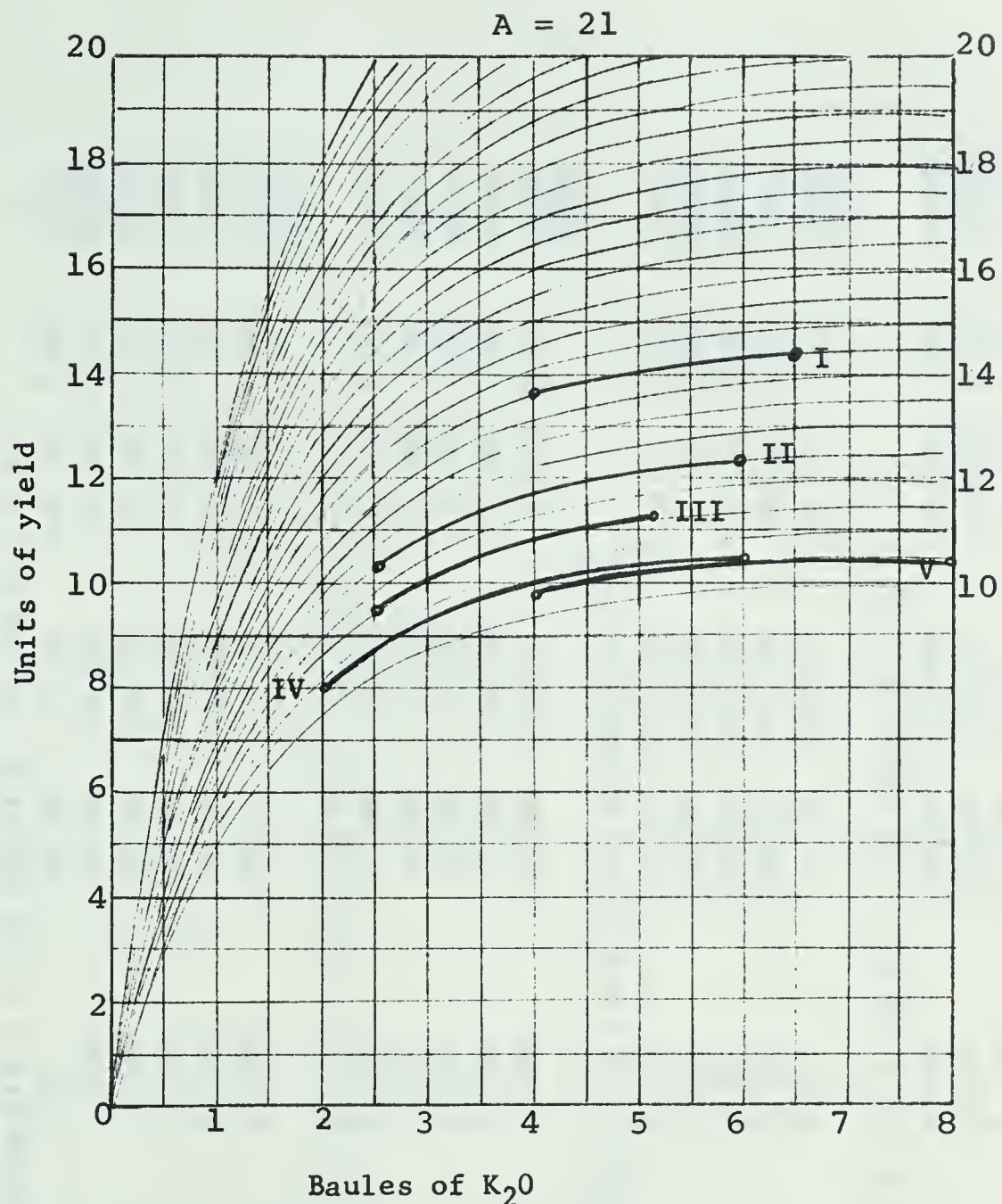


Fig. 8. Willcox's Relation of Tuber Yield to K_2O Applied
in Baule Units:

A = Maximum yield

I = Winterburn, 1964 ... $A = 14.5$ tons an acre

II = Winterburn, 1963 ... $A = 12.5$ tons an acre

III = Fort Saskatchewan, 1963 ... $A = 11.5$ tons an acre

IV = Fort Saskatchewan, 1964 ... $A = 10.5$ tons an acre

V = Parkland, 1964 ... $A = 21$ tons an acre

(The yield of Parkland 1964 trial was divided by
the factor 2, to fit in this diagram).

Table V. Yield of Irish Potato Tuber as Affected by Varying Rates of Potash Applications Expressed by Means of the Mitscherlich-Baule-Willcox Equation.

K ₂ O Applied		Original K in Soil		Soil + Applied		Yield (Ton/acre)		Deviation	
Baule lb/acre	Units	Soil Test lb/acre	Estimated Baule Units	Baule Units	Found (A)	Calculated (B)	B - A	% of A	X ²
Experiment I. Fort Saskatchewan (1963) $\log (11.2 - y) = \log 11.2 - 0.301 (x + 2.5)$									
0	0	136	2.5	2.5	8.96	9.20	+ 0.24	2.68	.0063
55	0.724	136	2.5	3.224	10.10	10.00	- 0.10	0.99	.0010
110	1.447	136	2.5	3.947	10.30	10.50	+ 0.20	1.90	.0038
220	2.895	136	2.5	5.395	10.96	10.95	- 0.01	0.09	.0000
330	4.342	136	2.5	6.842	11.10	11.10	0.00	.00	.0000
440	5.789	136	2.5	8.289	10.43	11.15	+ 0.72	6.90	.0465
									<u>.0576</u>
Experiment II. Fort Saskatchewan (1964) $\log (10.5 - y) = \log 10.5 - 0.301 (x + 2)$									
0	0	74	2.0	2.00	7.84	7.875	+ 0.035	0.45	.0002
120	1.58	62	2.0	3.58	9.74	9.630	- 0.110	1.13	.0013
180	2.37	76	2.0	4.37	9.99	9.810	- 0.180	1.80	.0033
240	3.16	60	2.0	5.16	9.49	10.196	+ 0.706	7.40	.0489
200	4.00	70	2.0	6.00	10.44	10.44	- 0.000	0.00	.0000
									<u>.0537</u>
Experiment III. Winterburn (1964) $\log (14.5 - y) = \log 14.5 - 0.301 (x + 2.5)$									
0	0	124	2.5	2.50	13.20	11.93	- 1.27	0.62	.1352
120	1.58	130	2.5	4.08	13.60	13.60	0	0.00	.0000
180	2.37	132	2.5	4.87	13.87	13.90	+ 0.03	0.22	.0001
240	3.16	114	2.5	5.66	14.22	14.21	- 0.01	0.07	.0000
300	4.00	130	2.5	6.50	14.30	14.33	+ 0.03	0.21	.0001
									<u>.1354</u>
Experiment IV. Parkland (1964) $\log (21.2 - y) = \log 21.2 - 0.301 (x + 4.1)$									
0	0	100.0	4.1	4.10	19.99	19.98	- 0.015	0.075	.00001
120	1.58	106.0	4.1	5.68	20.69	20.79	+ 0.100	0.480	.00000
180	2.37	100.8	4.1	6.47	20.02	20.96	+ 0.940	4.700	.04215
240	3.16	77.6	4.1	7.26	20.42	21.42	+ 0.640	3.200	.01948
300	4.00	101.6	4.1	8.10	21.10	21.12	+ 0.020	0.094	.00001
									<u>.06065</u>

significant difference between the found and the calculated. X^2 values were also calculated to test the goodness of fit, and were found not significant.

Due to a high level of variability existing in the soil of the Parkland plots, data failed to fit in this diagram.

B. 1964

The 1964 data were used in the Standard Yield Diagram (Fig. 8) in the same manner as in 1963. As indicated by t tests and X^2 tests, there were no significant differences between the empirical and the estimated yields.

VI. TUBER YIELD AND SOIL EXCHANGEABLE POTASSIUM

Bray's Modification of the Mitscherlich Equation

The two year data (1963 and 1964) of tuber yield and soil exchangeable potassium in pounds per acre were used in Bray's Modification of the Mitscherlich equation to calculate the proportionality constant c_1 and c .

The equations used for these calculations were as follows:

$$\log (100 - y) = \log 100 - (c_1 b_1 + cx) \quad (1)$$

when no potash was applied ($x = 0$), then

$$\log (100 - y_0) = \log 100 - c_1 b_1 \quad (2)$$

$$c_1 = \log \frac{100}{100 - y_0} \div b_1 \quad (3)$$

$$c = [\log 100 - \log (100 - y) - c_1 b_1] \div b \quad (4)$$

$$y = 100 - \text{antilog} (2 - c_1 b_1 - cx) \quad (5)$$

y_0 = per cent of maximum yield without potash fertilization

y = per cent of maximum yield with some potash fertilization

b_1 = soil potassium in lb/acre, determined by soil test

x = potash applied in lb/acre

c_1 = effect factor for b_1

c = effect-factor for x

The yield found and yield calculated are given in Table VI.

The yields found and the yields calculated from the equation were taken as paired data for t tests. The calculated t values were smaller than the t value tabulated for significance indicating no significant difference between the found and calculated.

When tested for goodness of fit, the χ^2 values were not significant.

A tentative potato fertilizer requirement table (page 82) was prepared based on the Bray's modification of Mitscherlich equation:

$$\log (100 - y) = \log 100 - (c_1 b_1 + cx) \quad (1)$$

Table VI. Yield of Irish Potato Tubers as Affected by Varying Rates of Potash Application
Expressed by Bray's Modification of the Mitscherlich Equation.

$$\log (100 - y) = \log 100 - (0.0074b_1 + 0.004x)$$

Quantity of Potassium			Yield in tons/acre		Deviation		X ²
Soil Test Before K ₂ O Application (b ₁) K, lb/acre	K ₂ O Applied (x) lb/acre	Soil Test After K ₂ O Application K, lb/acre	Obtained (A)	Calculated (B)	B - A	% of A	
Experiment I. Fort Saskatchewan (1963) Max. Yield = 11.1							
136	0	132	8.96	10.04	+ 1.08	12.05	0.1162
"	55	160	10.10	10.50	+ 0.40	3.96	0.0152
"	110	216	10.30	10.70	+ 0.40	3.88	0.0149
"	220	252	10.96	11.00	+ 0.04	0.36	0.0002
"	330	342	11.10	11.06	- 0.04	0.36	0.0002
"	440	540	10.43	11.08	+ 0.55	5.27	0.0273
							<u>0.1790</u>
Experiment II. Fort Saskatchewan (1964) Max. Yield = 10.44							
74	0	70	7.84	7.50	- 0.34	4.34	0.0154
62	120	110	9.74	9.30	- 0.44	4.52	0.0208
76	180	138	9.99	9.92	- 0.07	0.70	0.0005
60	240	232	9.49	10.02	+ 0.53	5.58	0.0280
70	300	268	10.44	10.23	- 0.21	2.01	0.0043
							<u>0.0690</u>
Experiment III. Winterburn (1963) Max. Yield = 12.3							
70	0	102	10.5	10.20	- 0.30	2.86	0.0088
"	55	120	10.8	10.99	+ 0.19	1.76	0.3285
"	110	178	12.1	11.52	- 0.58	4.79	0.0292
"	220	262	11.1	12.02	+ 0.92	8.28	0.0704
"	330	274	12.3	12.20	- 0.10	0.81	0.0008
"	440	428	11.5	12.26	+ 1.16	10.08	0.1098
							<u>0.5475</u>

" = from pooled sample

Table VIa. Yield of Irish Potato Tubers as Affected by Varying Rates of Potash Application Expressed by Bray's Modification of the Mitscherlich Equation.

$$\log(100 - y) = \log 100 - (0.0074b_1 + 0.004x)$$

Quantity of Potassium			Yield in tons/acre		Deviation		X ²
Soil Test Before K ₂ O Application (b ₁) K, lb/acre	K ₂ O Applied (x) lb/acre	Soil Test After K ₂ O Application K, lb/acre	Obtained (A)	Calculated (B)	B - A	% of A	
Experiment IV. Winterburn (1964)							
124	0	Max. Yield = 14.30					
		140	13.20	13.01	- 0.19	1.44	0.0028
130	120	180	13.60	13.34	- 0.26	1.91	0.0051
132	180	196	13.87	14.00	+ 0.13	0.94	0.0012
114	240	200	14.22	14.07	- 0.15	1.06	0.0016
130	300	244	14.30	14.12	- 0.18	1.26	0.0128
<u>0.0235</u>							
Experiment V. Parkland (1963)							
118	0	Max. Yield = 21.45					
		104	18.1	18.6	+ 0.5	2.76	0.0134
"	55	120	19.4	20.5	+ 1.1	5.67	0.5900
"	110	148	18.3	20.9	+ 2.6	14.21	0.3240
"	220	186	17.7	21.2	+ 3.5	19.78	0.5778
"	330	200	21.5	21.4	- 0.05	0.23	0.0001
"	440	360	17.5	21.4	+ 3.92	22.40	0.7200
<u>2.2253</u>							
Experiment VI. Parkland (1964)							
100.0	0	Max. Yield = 21.1					
		124.4	19.99	18.57	- 1.42	7.10	0.1080
106.0	120	174.4	20.69	20.50	- 0.19	0.92	0.0020
100.8	180	172.4	20.02	20.64	+ 0.62	3.10	0.0186
77.6	240	204.8	20.42	20.65	+ 0.23	1.13	0.0025
101.6	300	232.4	21.10	20.95	- 0.15	0.72	0.0011
<u>0.1322</u>							

" = from pooled sample

The effect-factors calculated from the trials conducted and reported earlier are:

$$c_1 = 0.0074 \qquad c = 0.004$$

Therefore:

$$y = 100 - \text{antilog} (2 - 0.0074 b_1 - 0.004x) \qquad (2)$$

where:

b_1 = soil exchangeable potassium in lb. per acre

x = potash applied, in lb. per acre

y = percentage of maximum yield

Bray's relation between percentage maximum tuber yields and exchangeable potassium levels in soil is illustrated in Fig. 9.

VII. TUBER YIELD AND POTASSIUM CONCENTRATION IN PLANTS

Bray's modification of Mitscherlich equation was used to evaluate the relationship between tuber yields and percentage of potassium in oven-dried leaf petioles at mid-season.

The equations and calculations used in this evaluation were the same as used in the evaluation of the relationship between tuber yields and exchangeable potassium levels as given previously.

The calculated c_1 is equal to 0.146 and c , 0.0037 in the following equation.

$$\log (100 - y) = \log 100 - (0.146b_1 + 0.0037x)$$

y = percentage of maximum yield

b_1 = K% in leaf

x = lb/acre K_2O applied.

This relationship is illustrated in Fig. 10. A fertilizer requirement table was prepared based on this relationship (page 83).

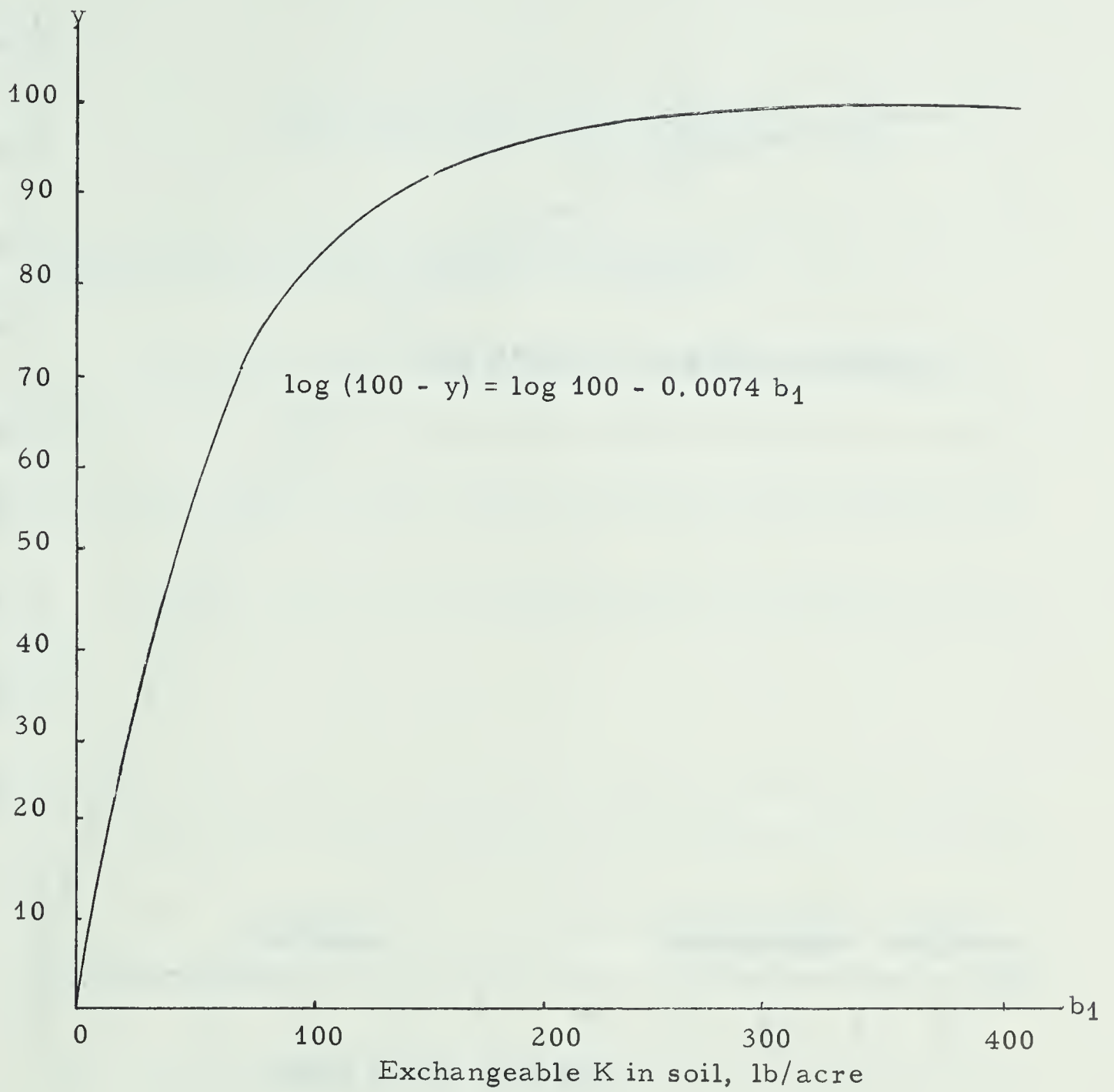


Fig. 9. Bray's relation of percentage of maximum tuber yield to exchangeable potassium in soil, lb/acre.

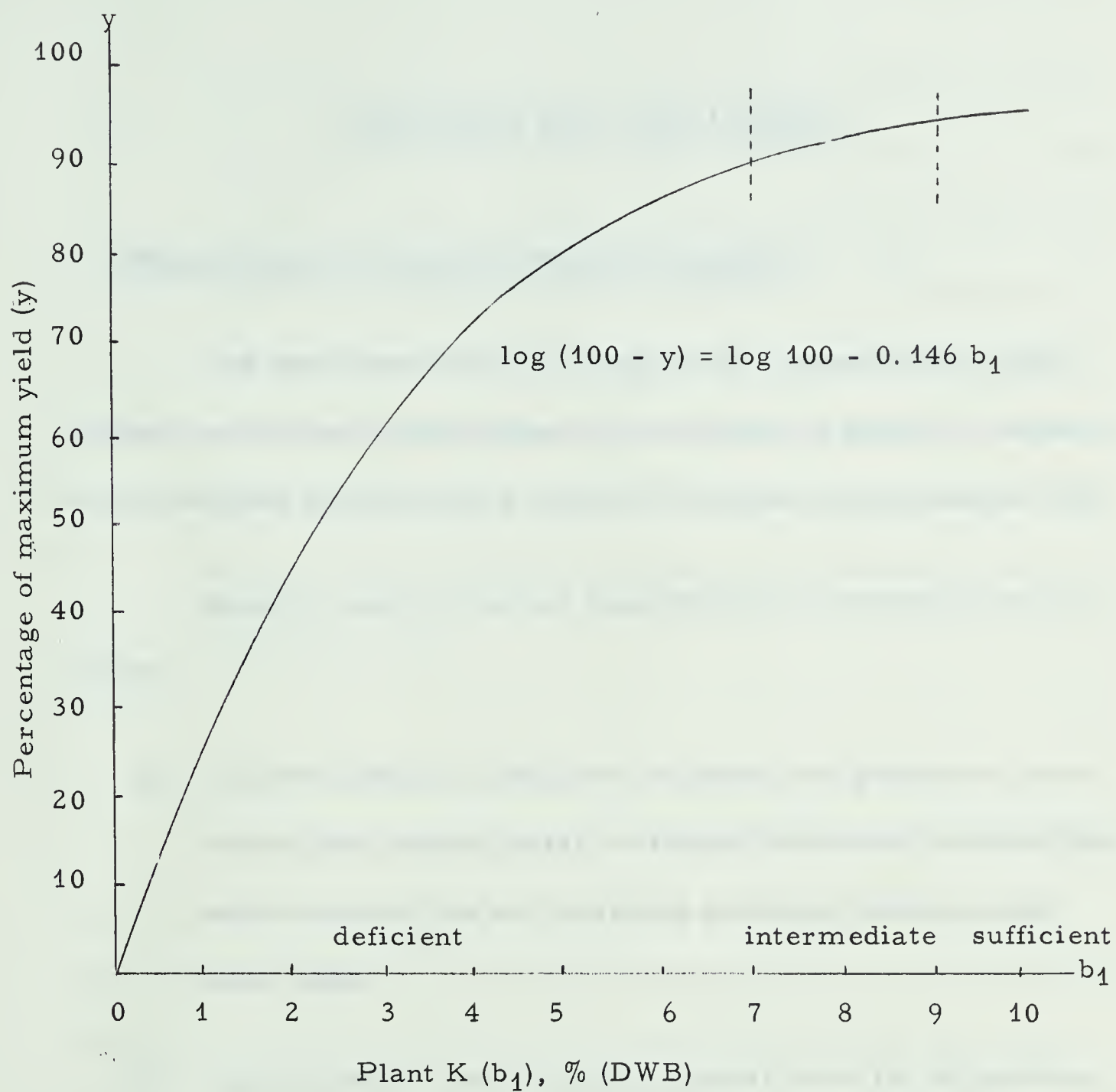


Fig. 10. Bray's relation of percentage maximum tuber yield to percentage potassium in potato leaf petioles (DWB) at mid-season.

DISCUSSION AND CONCLUSIONS

1. Plant Analysis Contrasted with Soil Analysis

The data herein reported support the contention that plant analysis to determine the nutrient concentration in plants, is superior to soil analysis in providing a basis for fertilizer requirements (54).

Specific results obtained supporting this contention were as follows:

- (a) The percentage of potassium in potato leaf petioles at mid-season (dry weight basis) correlated with tuber yield slightly better than did the soil available potassium based on soil tests taken.
- (b) The potassium concentration in plants from the Winterburn plots was higher than in plants from either Fort Saskatchewan or Parkland plots. The soil available, potassium of these three locations was at a comparable level. This would mean (1) the soil available potassium was only a crude estimation of the total available potassium in the soil; e.g., when exchangeable potassium was removed by plants, its rate of the replenishment

by the conversion of the non-exchangeable potassium to the exchangeable form was not measurable by a single soil test; (2) The total soil available potassium available to plants was subject to the influence of such factors as soil moisture and soil aeration. (3) Since the potassium concentration in the plants was an integrated value of all the factors that had influenced this concentration up to the date the sample was taken, the soil potassium fertility can be estimated by a single plant test.

On the other hand, because the potassium concentration in the plant is a value influenced by many factors, a low plant potassium concentration does not necessarily mean that there is a need of potash fertilizer in the soil since this nutrient deficiency could have been caused by the level of other factors being less than optimum.

However, since significantly positive correlations were found between soil test results and tuber yields as well as between plant test results and tuber yields, these two methods, soil test and plant test,

in a practical sense, are both considered desirable and essential in solving some of the problems regarding the prediction of fertilizer requirements.

2. Willcox's System Contrasted with Bray's Relationship

Willcox's standard yield diagram was found useful in these experiments in the interpretation of yield data, as well as in estimating the soil's original potassium availability (b) in terms of baule unit of K_2O . Once the potassium supplying power already present in the soil (b) has been determined with experimental yield data, the effect of the additional fertilizer can then be evaluated in the terms of percentage of the decrement from the maximum yield to the yield produced by the original soil fertility. Since the b values found in these experiments were measured by crop yields, and since the crop yields are influenced by a number of factors, the b values were not consistent with the single factor soil available potassium, determined by soil tests.

Bray's modification of Mitscherlich's equation has the advantage that it makes possible the measuring of soil nutrient supplying power directly by a single soil test, rather than indirectly by crop yield as in Willcox's system. Variation among C_1 values and among c values were found in these experiments as has been found by other workers (24, 38). The method used here to derive a general C_1 value from an accumulation of C_1 values, from trials conducted 1963 - 1964

on three locations, was somewhat different from Bray's original device (11).

Bray suggested that when a sufficient number of C_1 values were calculated from experimental data obtained from a variety of soils over a number of years, a general C_1 value could be derived by simply eliminating the extremely low and extremely high values and taking the average of the rest. This would require some experience or a natural insight.

Since C_1 is the angle of the logarithmic curve, in the equation

$$\log (100 - y) = \log 100 - (c_1 b_1 + cx) \quad (1)$$

when $x = 0$, equation (1) becomes

$$\log (100 - y_0) = \log 100 - c_1 b_1 \quad (2)$$

$$c_1 = \log \frac{100}{100 - y_0} / b_1$$

when $b_1 = 0$, $\log \frac{100}{100 - y_0} = 0$, and $c_1 = 0$

When b_1 is plotted against $\log \frac{100}{100 - y_0}$, all the c_1 points should be in a line that pass through the origin. By approximation a straight line can be drawn from the origin and pass through most of the c_1 points, eliminating only those points that are scattered too far away from the general trend. The value of this line is the general factor c_1 .

After the general effect-factor c_1 is obtained, c can be determined by the same method mentioned above.

$$c = (\log \frac{100}{100 - y} - c_1 b_1) / x \quad (3)$$

$\log \frac{100}{100 - y} - c_1 b_1$ is plotted against x , the c points would form a straight line that pass through the origin. By approximation a straight line can be determined from the origin to pass through the line formed by c points, and eliminate only those points that are scattered away from this general trend. The value of this line would be the general factor c .

c_1 value and c value found from these experiments are not in line with those found by Heeney and his associates (26).

	<u>Edmonton</u>	<u>Southwestern Ontario</u>
c_1	0.0074	0.00369
Standard error of the mean	$\pm 2\%$	$\pm 11\%$
c	0.0040	0.00630
Standard error of the mean	$\pm 4\%$	$\pm 38\%$

Since the deviation of the obtained yields from the estimated yields was not significant, a tentative fertilizer requirement Table A based on the equation $\log (100 - y) = \log 100 - (0.0074b_1 + 0.0040x)$ was prepared to serve as a general conclusion to this study.

Table VII. Potato Fertilizer Requirement Table A.
(Based on Soil Test)

Soil Test K, lb/acre	Fertilizer Requirement for 95% Yield K ₂ O, lb/acre	Percentage Yield without K ₂ O
30	270	40
50	233	57
70	196	70
90	159	78
110	122	85
130	85	89
150	48	92
170	11	94
176	0	95
190	0	96

Table VIII. Potato Fertilizer Requirement Table B.
(Based on Plant Test)

Plant K, %	Fertilizer Requirement for 95% Yield K ₂ O, lb/acre	Percentage Yield without K ₂ O
1	340	29
2	273	49
3	233	64
4	194	74
5	154	81
6	115	87
7	76	90
8	36	93
9	0	95
10	0	97

Similarly potato fertilizer requirement Table B was prepared based on the equation, $\log (100 - 95) + 100 - (0.146b_1 + 0.0037x)$ to serve tentatively as a general guide. The standard error of the estimated c_1 value of $\pm 1.9\%$ is much more desirable than that obtained by Heeney (26).

It is shown in this Table B as well as in Fig. 10 that potato leaf petioles at mid-season containing from 1 to 7 per cent potassium on a dry weight basis would be considered deficient of this element, 7 to 9% to be intermediate, and above 9% to have sufficient supply of this nutrient. This is consistent with the levels found in California by Tyler (51, 52, 53).

3. Tuber Yield Response To Potash Application

A. 1963

Fort Saskatchewan - with the application of 220 lb. per acre of potash, an increase of 2 tons of tubers per acre was obtained. The original soil exchangeable potassium was 136 lb. per acre.

Parkland - An increase of 3 tons of tubers per acre was obtained with 330 lb. per acre of potash applied. The original soil exchangeable potassium was 118 lb. per acre.

Winterburn - Although the soil exchangeable potassium at this location was the lowest (70 lb. per acre) as compared to Fort

Saskatchewan and Parkland, meaningful yield increase upon potash application was not obtained. This was probably due to the fact that two thirds of the plants in two replications were damaged accidentally.

At each of the three locations, the plot that received 330 lb. per acre of potash gave the highest tuber yield. Beyond this point, the yield responses in all the three locations, declined slightly; i.e., the plot that received 440 lb. per acre of potash produced a lower tuber yield than the plot that received 330 lb. per acre of potash.

B. 1964

Fort Saskatchewan - two tons per acre tuber yield increase was produced with 180 lb. per acre potash applied. The original soil exchangeable potassium was about 70 lb. per acre.

Winterburn - one ton per acre tuber yield increase was produced with 240 lb. per acre of potash applied to the soil. The original soil exchangeable potassium was about 126 lb. per acre.

Parkland - no significant yield increase was observed. The original soil exchangeable potassium at this location was about 100 lb. per acre. In each of the three locations, the highest yield was obtained from the plot that received 300 lb. per acre of potash (K_2O).

4. Effect of Potash on Specific Gravity of Tubers

A. 1963

The specific gravity of tubers, tested in 1963, was generally depressed slightly with the use of potassium fertilizer, but in all the plots the tubers with the lowest specific gravity, 1.082, were still considered fairly mealy, and were not beyond common acceptance.

B. 1964

The specific gravity of tubers, tested in 1964, was generally depressed slightly with the use of potassium fertilizer, but in all the plots the tubers with the lowest specific gravity, 1.068, were still considered fairly mealy, and were not beyond common acceptance.

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